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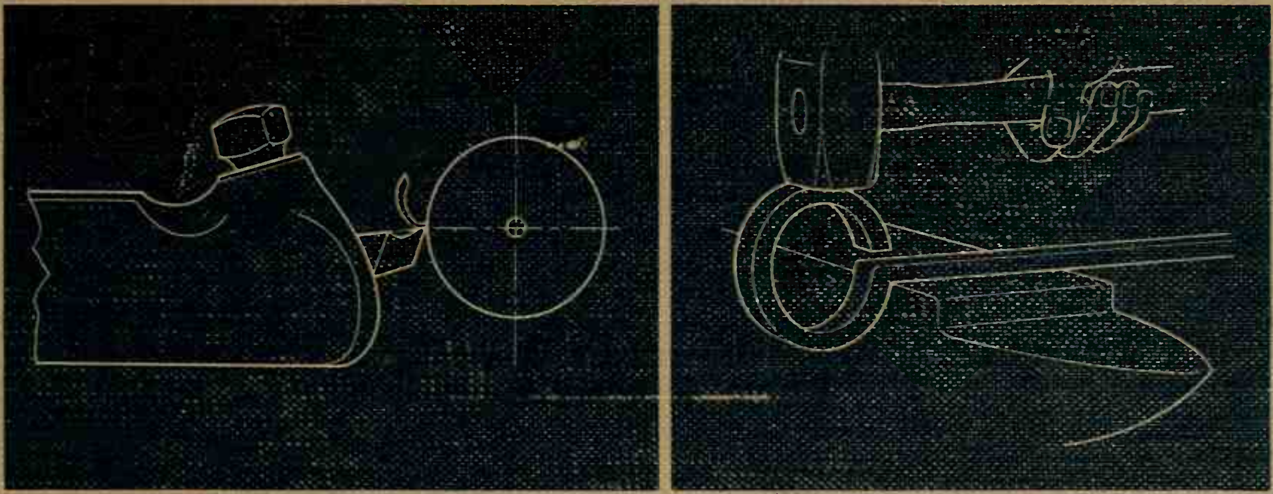

Metalworking

T. Gardner Boyd

BUILD-A-COURSE Series

WORKING

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INTRODUCTION

This book is one of a series planned specifically to provide general exploratory experiences in Industrial Arts. It is designed to provide a broad experience in METALWORKING through the use of tools, machines, and materials that are basic to this important area.

The book includes informational topics, general occupational information, planning and designing, safety, bench metal, sheet metal, forging, founding, heat treating, and machine shop. Although some shops may not be equipped to teach all the areas presented, students will have an opportunity to read about the several areas of metalwork.

Hand tool operations are stressed since this course is designed for the student who is beginning his study of metalwork, or has had very little experience in this area. Each unit progresses from the use of simple hand tools to some of the more basic machine operations, so the student can gain the necessary background of information and skill needed, as he progresses to more advanced metalworking.

A number of shop-tested projects are presented which will help stimulate interest and provide a challenge. The projects range from simple projects to some which are more complex.

The author hopes that this book will contribute to the student's knowledge and skill needed for everyday living, as well as his pursuit of vocational and avocational interests.

T. Gardner Boyd

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CONTENTS

METAL IN OUR EVERYDAY LIVES

UNIT 1

SOME ANSWERS TO THESE QUESTIONS:

1. Why should you study metalwork?
2. What does the future hold for metalworking industries and employment?
3. What occupational opportunities are available in the areas of metalwork and related fields?

A CHAT WITH YOUR TEACHER

The metalworking industries and their products play an important part in the lives of all of us. Through metal products our homes have been made more comfortable, sanitary, and convenient places to live. Our modes of transportation have become more luxurious and convenient with automobiles, streamlined trains, and jet airplanes.

Metals and metal alloys have played a very important part in the development of rockets and satellites. Metal undoubtedly will play an ever increasing roll as space ships and other items are developed for our adventures to other planets.

We are all consumers of metal products. Our homes are filled with items made of metal such as washing machines, refrigerators, metal furniture, automobiles, bicycles, and many other products which we use every day. To be an intelligent user of these articles you should be able to recognize good design and quality craftsmanship. The skills you learn in metalwork will help you as a consumer and will also enable you to repair and maintain many of these metal products. You may also develop a fascinating hobby making useful articles of metal.

METALS IN THE FUTURE

As we look into the future it is possible to visualize still further progress in the utilization of metal, especially when we consider our vast mining resource, huge steel mills, refining plants, and the progress our scientists are making in the development of new metal alloys. America's entry into the space age will create thousands of new and interesting jobs. In order to keep pace with the new developments in the aircraft, missile, and spacecraft field as well as our everyday needs, increasing numbers of engineers, scientists, technicians, and skilled craftsmen will be needed.

A recent census report reveals that more than 10 per cent of the people in our country are directly or indirectly engaged in some phase of the metalworking field. There are many different career and job offerings in each area of metalwork. Industry needs engineers and skilled technicians to plan and supervise the work. Skilled craftsmen are needed to perform the more difficult machining and fabricating operations. Semi-skilled people are needed to operate production machines, and to do the many routine jobs.

Fig. 1-1, lists the areas of metalwork you will be studying in this book, and a partial list of the job or occupational classifications, which offer excellent paying jobs.

It is impractical to offer, in the school shop, training in all of the specific jobs

listed in Fig. 1-1, so our course will be concerned with the basic skills involved in the various areas.

As you study this book and explore the various areas by constructing the projects you design, or those described in the Project Section, you will discover which areas you like best. If you enjoy metalwork and do well in your work, you should give serious thought to taking up some phase of metalwork as your vocation.

	Jobs
Bench Metal	Basic To All Metalwork Bench Repairman Ornamental Iron Worker Iron Worker, Shop Riveter
Forging	Tool Dresser Hammersmith Blacksmith Spring Maker Hand Drop Hammer Operator Forging Press Operator Angle Press Operator Bolt Machine Operator
Foundry	Bench Molder Finish Molder Machine Molder Chief Inspector Die Casting Machine Operator Coremaker Blast Furnace Keeper Electric Arc Furnace Operator Sand Control Man Ladle Man
Heating Treating	Heat Treater Casehardener Tool Hardener Checker Material Tester Furnace Man Temperer
Machine Shop	Machinist Machine Shop Foreman Tool Supervisor Machinist, Bench Instrument Maker Tool and Die Maker Tool Maker Engine Lathe Operator Turret Lathe Operator Milling Machine Operator
Sheet Metal	Sheet Metal Worker Sheet Metal Layout Man Furnace Sheet Metal Worker Construction Sheet Metal Worker Sheet Metal Foreman Template Layout Man

Fig. 1-1. Job opportunities in the fields of metalwork.

DESIGNING METALWORKING PROJECTS

UNIT 2

1. Importance of good design.
2. Basic principals of good design.
3. Why it is necessary to know about materials used in metalwork when designing metal projects.

GOOD DESIGN

Design is more important in our every day lives than we sometimes realize. Did you ever stop to think about the part it played in the development and construction of the home you live in, and the furniture you use? Cars, airplanes, and rockets have all been developed from drawings on paper. Many of these products are pleasing in looks; some are not. You will want to learn to sense and recognize the good qualities in design so you can be a good judge of consumer products.

Our great industrial development has been successful largely because new and better ideas for products, processes, and machines are constantly being developed. Probably one of the biggest reasons the United States has become the leading nation in the world, is because each of us want new, different, and better products. To keep ahead our country needs people who can think seriously and creatively for themselves.

DESIGNING YOUR PROJECT

You can learn to design as you develop the projects you build in metalwork. Designing begins with a problem. It may be to invent and create a new product or to improve one that is already in use. Typical questions you will want to answer regarding the designing of your project are:

1. What is it for? What is the purpose of the project and what must it do?
2. Are there any limitations involved? For example, if you are not allowed to use certain machines, can all parts be made without them? Other limitations might be the availability of materials or processes to be used.
3. Has the problem been solved by others, if so, how can it be improved? Can it be designed to meet your particular needs?

After you can answer these questions satisfactorily your next step is to:

1. Make several freehand sketches of your ideas so they can be studied by you and your teacher. While studying your sketches, consider several different designs of the project and the kind of material to be used for each part.
2. Make desirable changes. Then, make a working drawing which can be used to guide your construction of the project. Also make full-scale drawings of the parts which have irregular shapes.
3. Decide what kinds of material you will use. Is one kind of metal to be used or a combination of metals? Will you use bars, sheet, pipe, or cast metal?
4. Plan the procedure you will follow to construct your project.

As you design projects you will need to consider certain basic elements and prin-

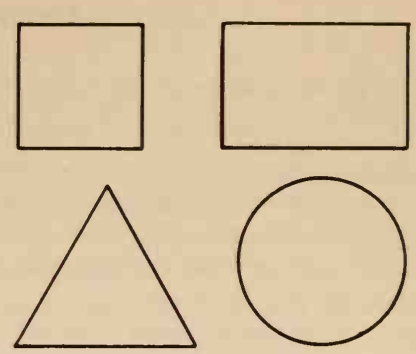


Fig. 2-1. Left, Combinations of lines are used to form shapes. Fig. 2-2. Right, Four basic shapes.

ciples that make up the over-all design of an article. Study the following basic elements and principles of design:

1. Line. All things we can see have line. Buildings, cars, trees, flowers, and birds are all made up of lines, Fig. 2-1. There are three principal types of line--straight, curved, and circular. These lines when properly combined give an article a pleasing shape.
2. Shape. There are four basic shapes--square, rectangular, triangular, and round, Fig. 2-2. You see these shapes, or a combination of these shapes, when you look at nature, or man-made objects. Shape is influenced by function.
3. Mass or Solid. The solid shape or outline of an object has dimensions of thickness, width, and height. When you look at an object the mass may be square, round, or some other geometric form, Fig. 2-3. You will use rods, bars, cubes, and sheets of metal in developing your projects to make up a Mass or Solid shape.
4. Proportion. The relationship between dimensions is called proportion. This relationship may be as a ratio. The "golden rule" is a proportion of about 5 to 8. Odd ratios such as 3 to 5, 7 to 9, 9 to 11 are usually preferable. Rectangles, ovals, and free forms are more pleasing as a rule than are squares and circles, Fig. 2-4.

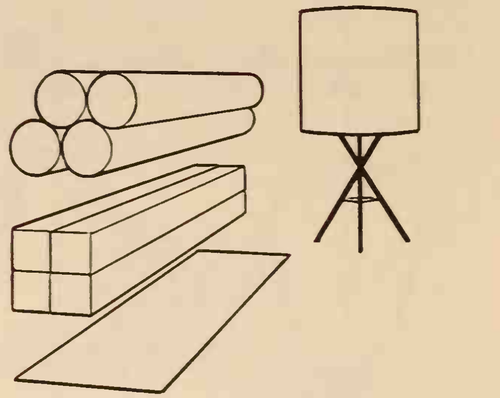


Fig. 2-3. Rods, bars, and sheets of metal are used to make up a larger shape or mass.

5. Balance. An object has balance when its parts appear to be of equal weight--neither top heavy, nor bottom heavy, nor lopsided. There are two kinds of balance:
Symmetrical Balance--When the

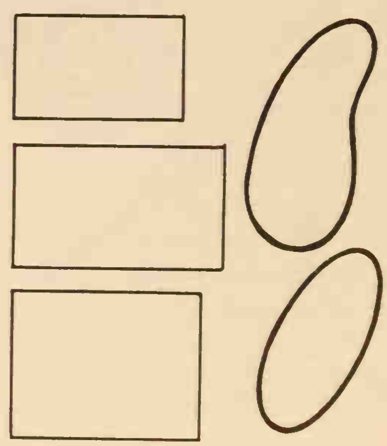


Fig. 2-4. Rectangles and free forms.

parts on each side of the center are alike in shape and size, Fig. 2-5 (A).

Informal Balance--When the design is such that the balance cannot be measured or laid out with a ruler, and yet you get the feeling that it is balanced, Fig. 2-5 (B). Informal balance is usually more interesting than symmetrical balance.

6. Unity. A design that has unity seems to bring the various parts together

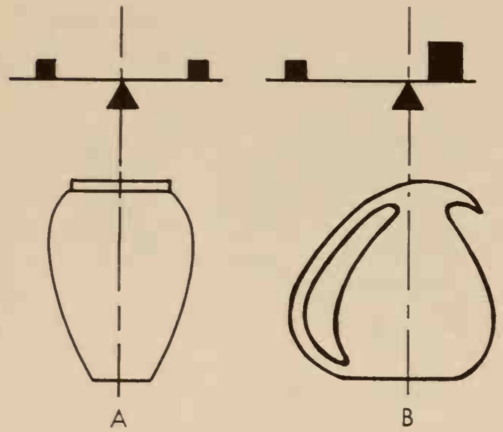


Fig. 2-5. (A) Symetrical balance, (B) Informal balance.

as a whole. Each part of the object seems to have a relationship and your eyes follow through and among the various parts with ease. See Fig. 10-10, page 97.

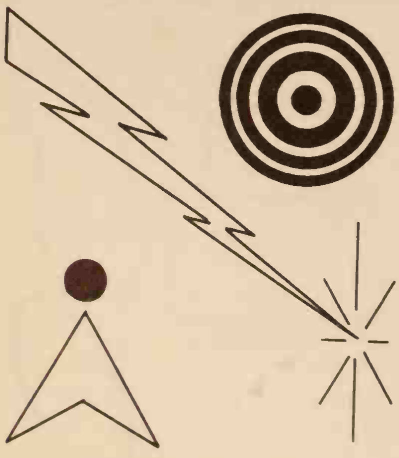


Fig. 2-6. Emphasis is brought out through shape, color, or decorations.

7. Emphasis. The design is given a point of interest. A certain part of the object may stand out through the use of color, its shape or the way it is decorated, Fig. 2-6.

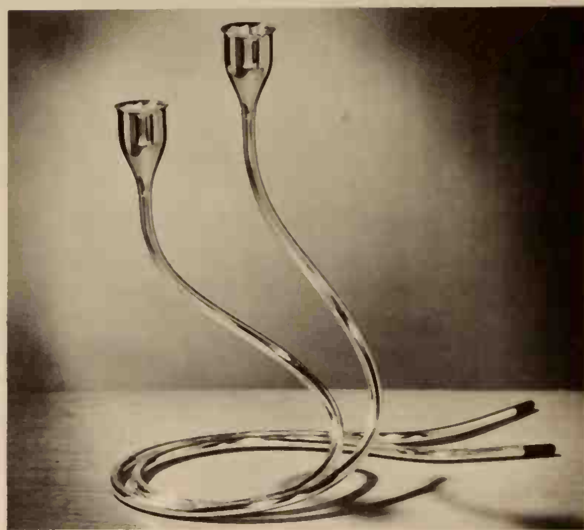


Fig. 2-7. In these candlesticks lines and curves are repeated to create rhythm.

8. Rhythm. Rhythm is achieved by repeating lines, curves, forms, colors, and the textures within the design. It gives an object a feeling of movement and a pleasing appearance, Fig. 2-7.

Fig. 2-8. In this design, harmony is obtained by using parts that fit and look well together.

9. Harmony. Harmony results when the different parts of a design fit and

look well together, Fig. 2-8. Too much harmony can make a design monotonous and uninteresting. Variety is then needed to make it more pleasing.

10. Texture. Texture is the condition of the surface of a material. Many metals have texture ranging from a smooth to a very coarse surface. Texture can be added by perforating, cutting, pressing, rolling, or expanding, Fig. 2-9. When applying texture to your design be sure it is appropriate to the article, and to its function.
11. Color. All metals have a color of their own. For example, aluminum is silvery, while copper is a rich reddish brown. Colors may also be added by using lacquer, paint, chemicals, or other finishing materials. The selection of color is important in any design. Colors must be chosen carefully, or they may ruin a perfectly good project. Ordinarily, one color should be dominant in the design. The main color should be appropriate for the project. The qualities of colors should be considered. Some colors, such as red, orange, and yellow have warmth while other colors, such as blue, purple, and green are cool.

SELECTION OF MATERIALS

In order to design and construct quality projects in metal work, you will need to become familiar with some of the more common materials used. It will be necessary for you to know something about the various properties of metal and the shapes and sizes available.

Metal is one of the most common elements found on earth. Some of the metals mined are: aluminum, copper, gold, silver, and iron. You have probably heard someone speak of an alloy. An alloy is a combination of two or more metals melted and mixed together in certain proportions. For example, brass is a metal alloy which is produced by mixing copper and zinc. The properties of base metals and metal alloys vary widely. Among these properties are:

1. Hardness, the resistance to surface abrasion or penetration. Metal becomes harder as it is worked (by hammering on it) and by heat treating (explained in Unit 7). The harder the metal, the less likely it is to bend or change shape. Hard metals are more brittle than soft metals.
2. Malleability, the ability to be shaped by rolling out or hammering when cold.

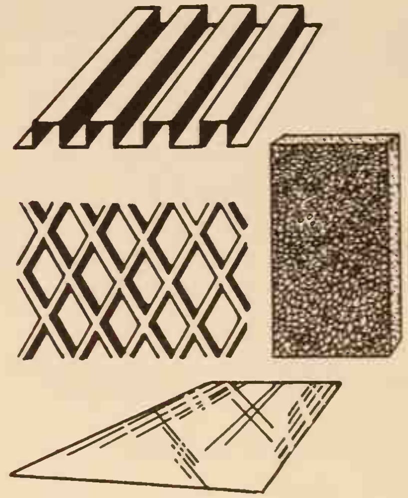


Fig. 2-9. Texture can be added by hammering, perforating, cutting, or forming the metal.

3. Ductility, the ability to undergo deformation (change of shape) without breaking.
4. Elasticity, the ability to return to the original shape after deformation.
5. Fatigue Resistance, the ability to resist repeated small stresses.

The metals you will use for projects will come under the following classifications:

1. Ferrous Metal (made from iron)
   a. Low-carbon steel which is often

called mild steel, contains about 0.15 to 0.30 per cent carbon. This is not enough carbon to harden the steel to any appreciable degree. This type of steel may be purchased in sheets, bars, and rods. It is easily formed, machined, and welded. You will use low-carbon steel for some of the projects you construct in bench metal work.

b. <u>Medium-carbon</u> steel contains about 0.30 to 0.60 per cent carbon. This type of steel works well for parts of projects which require machining.

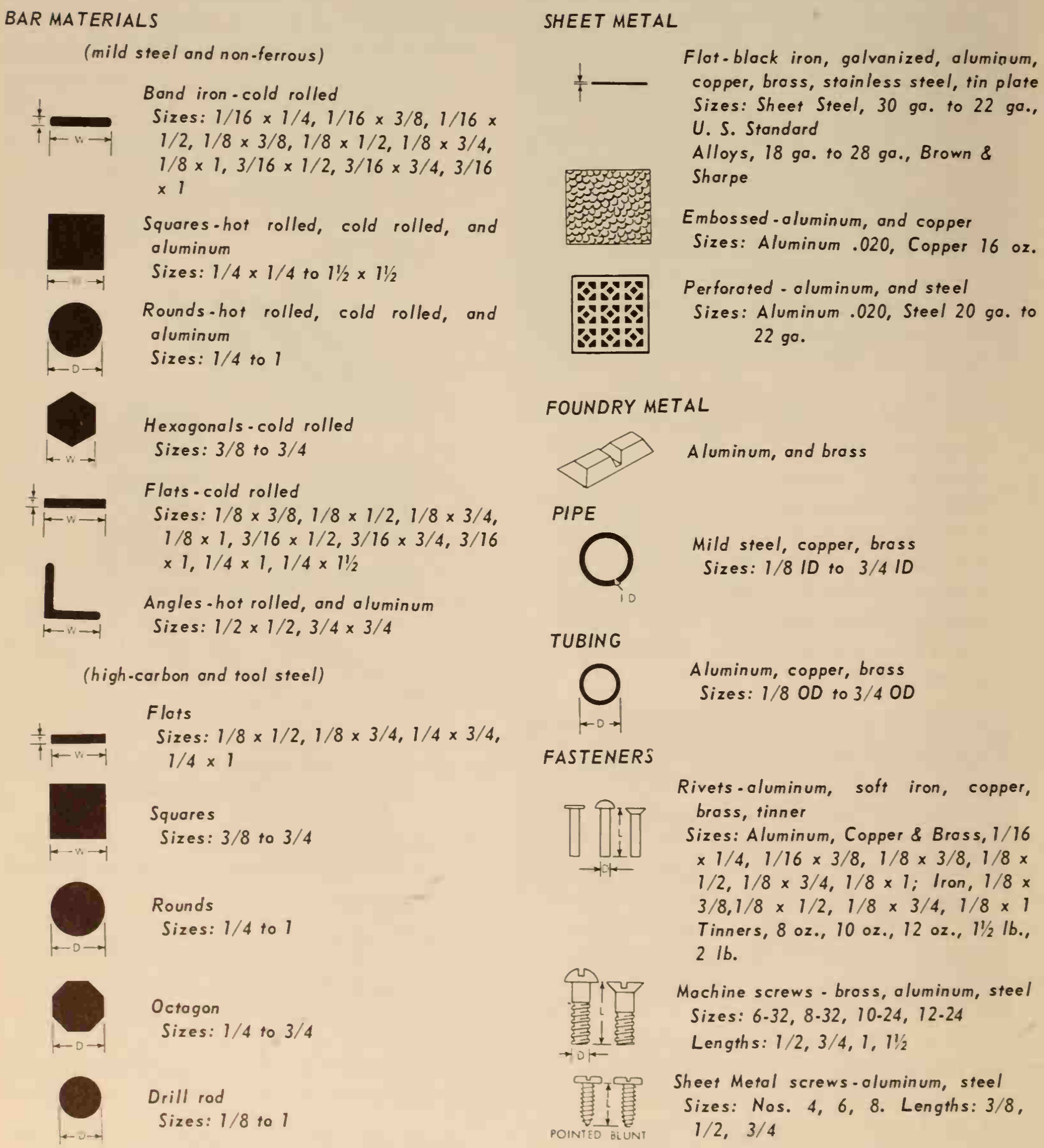


Fig. 2-10. Materials commonly used in metal work.

c. High-carbon steel contains from 0.60 to .100 per cent carbon. It is sometimes referred to as tool steel. Most school shops use high-carbon steel that has about 0.90 per cent carbon for chisels, punches, and similar projects, since this steel can be hardened and tempered.

2. Nonferrous Metal (made without iron)
   a. Aluminum is a bright, bluish metal which is light in weight and strong. There are many alloys of aluminum but most school shops stock only the softer kind, such as 1100-0 and 3003-0 in sheets. Rods, bars, and angles are used which have a harder temper. Aluminum alloys 43 and 108 are used for sand casting in the foundry. Aluminum is also used in shop work to construct bench metal, sheet metal, art metal, and machine shop projects.
   b. Brass is an alloy of copper and zinc. It has a gold color. It is very ductile (may be hammered or drawn out thin) and easy to saw and file. Brass provides a very interesting color contrast when used with other metals.
   c. Copper has a rich reddish brown color. It is easy to form and solder, but is hard to machine. Copper takes a beautiful polish. It is used for decorative articles such as bowls, trays, and lamps. It is also an excellent conductor of electricity.

COMMON SHAPES AND SIZES OF METAL

Choosing the correct metal for your project is very important. The proper size must be selected so your finished project will be strong, durable, and meet all of the principles of good design. Study Fig. 2-10, to become familiar with the various shapes, sizes, and characteristics of the more common metals. Fig. 2-10, also shows the most common metal fasteners. Become familiar with these fasteners so you can decide the best way to fasten the parts of your project together.

QUIZ - Unit 2

Write answers on separate sheet of paper. Do not write in book.

1. How will the study of design help you as a consumer?
2. List three things to consider when designing a project ---.
3. What do the basic elements of design, line and shape have in common?
4. The solid shape or outline of an object has dimensions of ---, ---, and ---.
5. The relationship between dimensions is called ---.
6. Rectangles, ovals, and free forms are more pleasing as a rule than, --- and ---.
7. Explain the difference between symmetrical balance and informal balance.
8. What is the purpose of emphasis in designing a project?
9. Texture can be added to metal by ---, ---, ---, or -.
10. List five properties of metals.
11. Ferrous metal is made from ---.
12. Nonferrous metal is made from ---.
13. High carbon steel contains from --- to --- per cent carbon.
14. Medium carbon steel works well for parts of a project requiring machining. (True or False).
15. Brass is an alloy of --- and ---.

METAL SHOP SAFETY

UNIT 3

1. The importance of a proper attitude toward safety.
2. Safety guides for dressing properly.
3. How to use metalworking tools safely.
4. Good housekeeping safety guides.

"Hi! I'm Sammy Safety. My ambition is to help you learn to work safely with tools, machines, and other equipment found in shops, and around the home so you won't get hurt. Injuries are painful and can be very serious. Many accidents occur because people are not informed. My job is to keep you informed and warn you when there is danger involved.

Study this lesson thoroughly and learn the safety guides listed. Watch for me as you study other lessons. I will be around to keep you informed and remind you about safety.

The proper safe attitude is very important in preventing accidents. This attitude is developed by accepting the guides and rules described in this book and demonstrated by your teacher. Safe practices and proper methods are for you, and not just the other fellow's. You are not a "sissy" if you wear goggles and use guards--you are smart. Just remember the right way is the safe way.

A football uniform is designed to overcome some of the hazards of the game. You know the dangers in playing the game without being properly dressed. The same holds true for the metalworker. While working in the metals area always dress properly for the job to be done and follow these guides:

1. Roll your sleeves above your elbows.
2. Remove your tie or tuck it in your shirt.
3. Remove wrist watch, rings and other pieces of jewelry which might get caught in moving machinery.
4. Keep your hair cut short or wear a shop cap to keep long hair from getting caught in machinery.
5. Wear a shop coat or apron to protect your clothing.
6. Wear special protective clothing when working in foundry, forging, and welding.
7. Wear safety goggles or a face shield when drilling, grinding, buffing or when there is danger of flying chips.
8. Wear special goggles or shield when welding.

It has been said that a good mechanic seldom gets hurt. A good mechanic takes proper care of the tools he uses. Records show that most minor accidents are caused by incorrect use of hand tools, or the tools have not been kept in good repair. When you are working with tools in the metals area always follow these guides:

1. Do not use a tool until you have had a demonstration.
2. Report any defective or broken tool you find to the teacher.
3. Dull tools are dangerous and will not work properly. Keep all cutting edges sharp.
4. Check hammer handles to be sure they are not cracked, and are fastened tightly.
5. Never use a file without a handle.
6. Always grind mushroom heads and

burrs off chisels, punches, and other small hand tools, Fig. 3-1.

7. Never carry sharp tools in your pocket.
8. Always carry tools and projects so their points or sharp edges are pointing down. If this is impractical, protect sharp edges and points with heavy paper, pieces of wood, or a metal sheath.
9. Be sure your hands are dry when using portable electric hand tools.

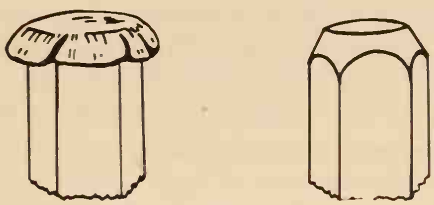


Fig. 3-1. The cold chisel at the left has a mushroom head. The one at the right is properly ground.

Do not stand in a wet spot, touch plumbing, or other grounded objects while using electrically powered tools.

10. Always ground portable electric hand tools. Check the electrical cord, connections, plug, and switch to be sure they are in good condition before using.
11. Do not use electrical tools around inflammable gases or vapors. This could cause an explosion.

To complete your safety program you will want to establish some good housekeeping guides. A clean and orderly shop provides a safe place to work. You will want to do your part in keeping the shop clean and in order. Clean the bench or machine after you have finished your work. Clean and put away all tools and accessories when you have finished using them. Wipe up any oil or grease which might have dropped on the floor. As you work in the shop you will discover other things you can do to make it a safer place to work. Always be alert for any situation that might cause an accident.

Remember these basic guides of safety and practice them:

1. Dress properly for the job.
2. Protect your eyes at all times.
3. Know your job and do it correctly.
4. Be a good housekeeper.
5. When in doubt check with your teacher."

QUIZ - UNIT 3

1. Describe the proper way to dress in the shop.
2. How are the eyes protected when:
   a. grinding?
   b. drilling?
   c. welding?
3. Why is the proper attitude an important factor in shop safety?
4. Why is it necessary to remove jewelry when working with moving machinery?
5. What kind of hand tools are most dangerous?
6. How should sharp tools be carried?
7. Why is it advisable to grind mushroom heads off chisels and punches?
8. List three safety precautions to be observed when using a portable electric drill.
9. Why is it dangerous to use electrical tools around inflammable gases or vapors?
10. Why is good housekeeping an important part of a shop safety program?

BENCH AND WROUGHT METAL

UNIT 4

1. How to use measuring and layout tools.
2. Cutting and drilling.
3. Bending and forming metal.
4. Cutting internal and external threads.
5. Fastening metals together.
6. Polishing and buffing metal.

Bench metal is basic to all areas of metal work. It deals with the use of common hand tools and information necessary for all workers in the metal trades. In this area of metalwork you will learn to use hand tools for laying out, cutting, shaping, forming, drilling, threading, assembling, and testing work at the bench. You will be working with mild steel, aluminum, copper, etc. The metal will be in the form of rods, squares, flat bars, and sheet stock of various sizes and thicknesses. The metal is worked cold with hand tools and a few machines such as the drill press, grinder, and buffer.

It is very important that you learn to use the hand tools which will be introduced in this unit, because you will use many of them in the other units of metalwork. Using hand tools correctly is often more difficult than operating some machines. A metalworker must be able to use hand tools skillfully. Aviation mechanics, auto mechanics, machine repairmen, and assemblers, to mention a few, offer excellent job opportunities to people who can use bench metal tools correctly.

Learning to use hand tools will be very valuable to you regardless of how you earn your living. You will be able to take care of maintenance jobs around your home. Many have found bench-metal work to be a very interesting and satisfying hobby. It does not cost as much to equip a home work shop for bench-metal work as some other hobbies. You can make many useful items for your home and gifts for friends.

MEASURING AND LAYING OUT STOCK

The first steps in constructing a project are to measure your stock and mark it to the correct size, then transfer your patterns to the material being used. Making accurate measurements is very important in the production of high-grade work. To do this you will want to learn to use the following measuring and layout tools correctly.

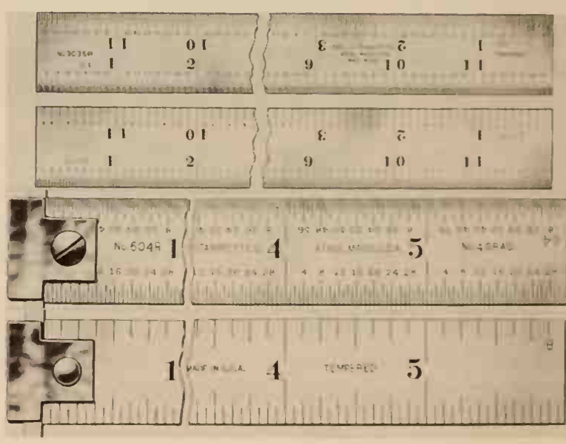


Fig. 4-1. Above. Two sides of a spring-tempered steel rule. Below. Two sides of an adjustable hook rule. (L. S. Starrett Co.)

RULES

The most widely used tool for taking and laying out measurements is the steel rule. Rules vary in lengths, widths, and thicknesses. The most common being 6, 12, and 24 inches in length. Along each edge of the rule and on both sides, the inch marks

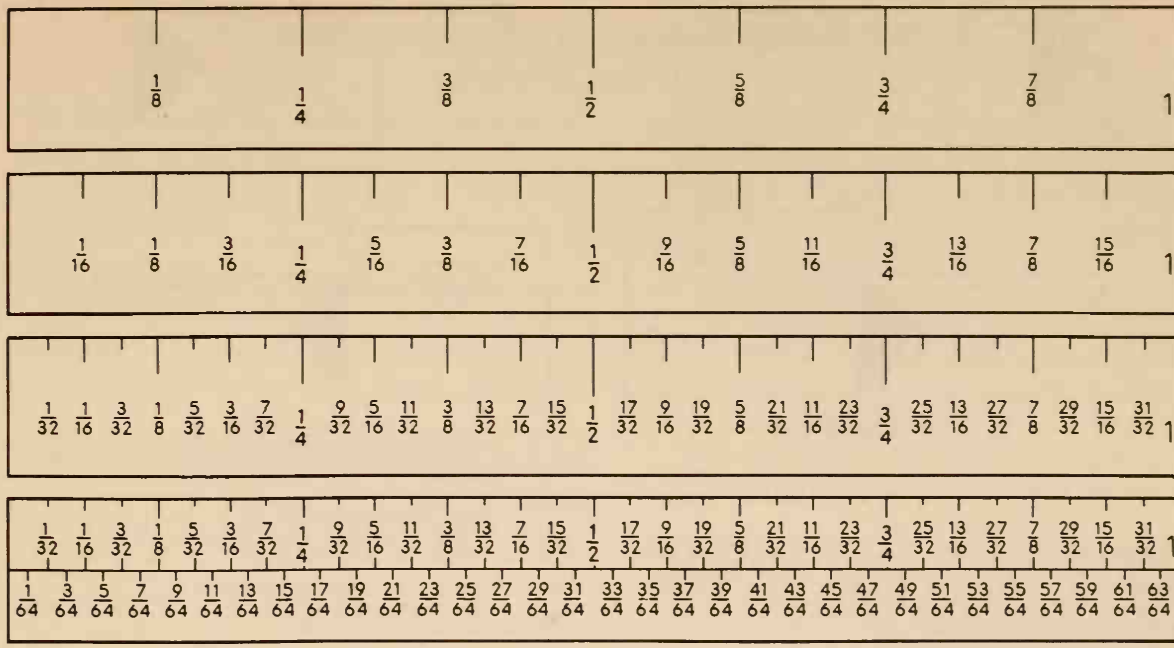


Fig. 4-2. Chart showing a comparison of the divisions on a rule.

are divided into various subdivisions. The first edge is divided into sixty-fourths of an inch. The second edge is divided into thirty-seconds of an inch and the third edge into sixteenths of an inch. The fourth edge, and the one you will use most is divided into eighths of an inch. Several types of steel rules with which you should become familiar are shown in Figs. 4-1.

Incorrect measurements in layout cause serious trouble in metalworking. Be sure you can read a rule. Study the chart shown in Fig. 4-2.

SCRIBER

A scriber is a pointed steel instrument which is used to scribe or scratch lines on most metal surfaces, Fig. 4-3. It is held

Fig. 4-3. A scriber. (L. S. Starrett Co.)

in the same manner as a lead pencil, Fig. 4-4. Keep the point true and sharp.

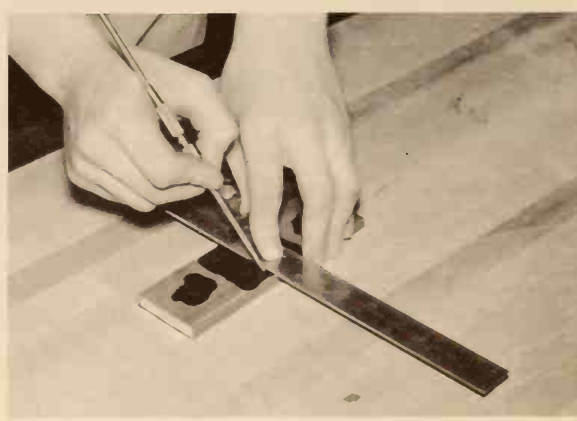


Fig. 4-4. Hold the scriber like a pencil.

SQUARES

The combination square set, with its four principal parts is a very useful measuring and layout tool, Fig. 4-5. The four parts are

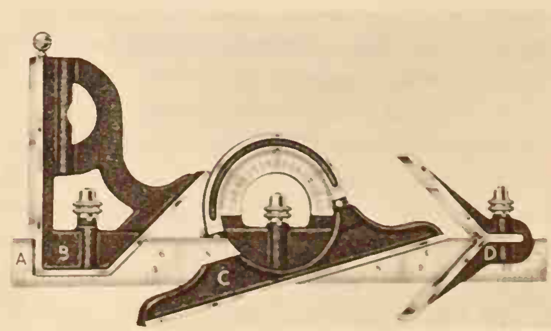


Fig. 4-5. Combination square set. A - blade, B - 45 and 90 deg. square head, C - protractor head, D - center head.

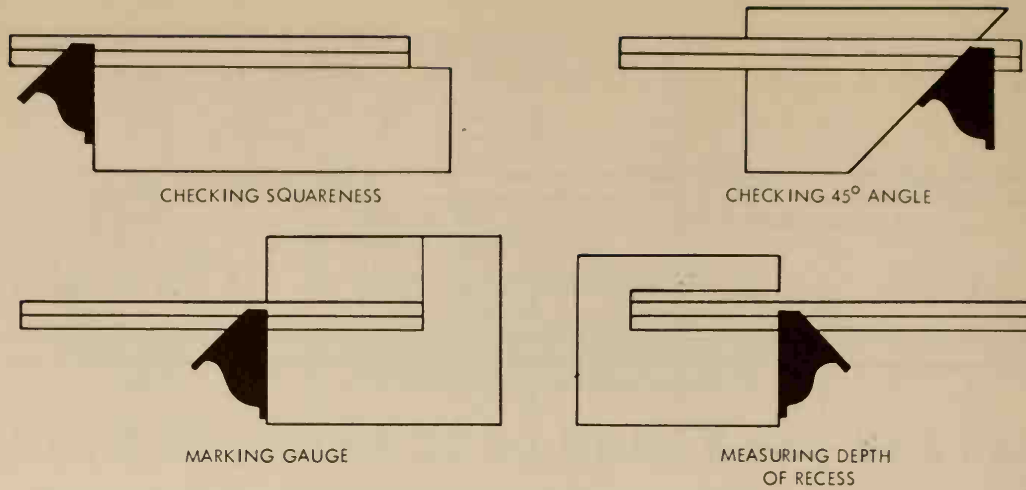


Fig. 4-6. Uses of the combination square head.

blade, combination square head, center head, and protractor head.

The blade which is available in lengths from 4 in. to 24 in. has graduations marked on all four edges. These graduations are usually 64ths, 32nds, 16ths, and 8ths. A groove runs along the center of the blade on one side and serves as a guide for clamping the heads. Each head can be slipped to any position along the length of the blade, and held in place with a knurled nut.

The combination square head has a straight edge which forms a 90 deg. angle with the blade on one side, and a 45 deg.

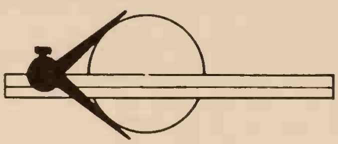


Fig. 4-7. Using the combination square center head.

angle on the opposite side. This head, Fig. 4-6, has many uses.

The center head has two projecting arms which form an inside angle of 90 deg. This head is used to locate centers of round stock. To use it for this purpose, place the center head against the stock with the blade on the top surface, Fig. 4-7, and scribe a line along the blade edge. Move the tool around the stock, and scribe two or more lines approximately the same distance apart. The exact center of the stock will be at the intersection of these lines.

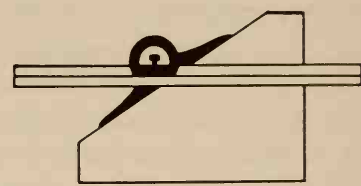


Fig. 4-8. Using the combination square protractor head.

The protractor head has a straight edge with a revolving turret in the center. The revolving turret is divided into 180 degrees. It is used to lay out or check any angle from 0 to 180 degrees. To draw angular lines, clamp blade to turret, set the blade at required degree, and lock in place with knurled nut. Then, place straight edge of head against edge of stock with blade across the surface, and scribe a line along the edge of the blade, Fig. 4-8.

DIVIDERS

Dividers are used for measuring or setting off distances, and to lay out arcs and circles, Fig. 4-9. The procedure for using

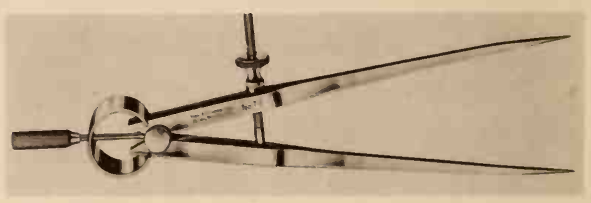


Fig. 4-9. Dividers. (L. S. Starrett Co.)

the dividers is the same as using a pencil compass in drawing.

PRICK PUNCH

The prick punch is a small center punch which is also known as a layout punch. Its point is ground at an angle of 30 degrees. It is used to accurately mark holes and

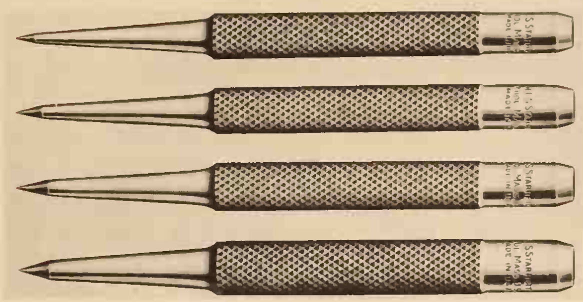


Fig. 4-10. A set of prick punches.

other locations to be machined, Fig. 4-10. Keep the point true and sharp.

CENTER PUNCH

The center punch has one end ground to a 90 deg. conical point, Fig. 4-11. It is used

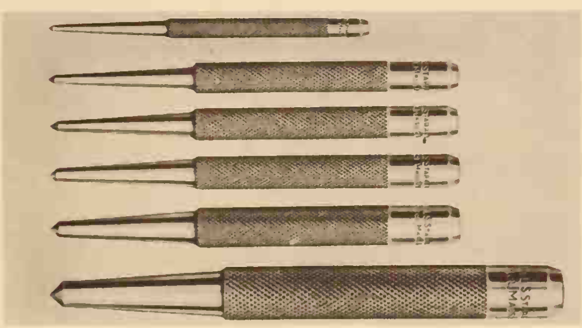


Fig. 4-11. A set of center punches.

to enlarge prick punch marks and make it easier for the drill to start correctly. Keep the point true and sharp.

LAYING OUT STOCK

In laying out a job, an outline or pattern marked on the material shows the size and shape of the parts and the location of openings and holes. Laying out work varies, so the procedure given here may be changed to meet your particular situation. Remember when laying out stock for a project, accuracy is very important.

1. Check the end of the material from which the marking is being done to make sure it is square. Square the end if necessary.
2. Measure the stock for required length by placing a rule parallel to

Fig. 4-12. Measuring length of stock. Mark length accurately with a scriber.

   the edge of the stock. Check the end of the rule to be sure it is even with the square end of the stock. Make a short mark in line with the unit on the rule that represents the correct length, Fig. 4-12.
3. Mark a square line across stock at the correct length by placing a square over the stock, Fig. 4-13. The straight edge of the square head must be held firmly against the edge of the stock. Holding the scriber at a slight angle away from the blade of the square, and slanted slightly along the direction the line is to be drawn, mark a line across the stock. Cut off stock to length.
4. Prepare work for lay out of holes, cutouts, and irregular shapes by coating the surface with layout "bluing" fluid. This dries fast and provides a contrast between surface and scribed lines, Fig. 4-14.
5. Draw center lines across the length

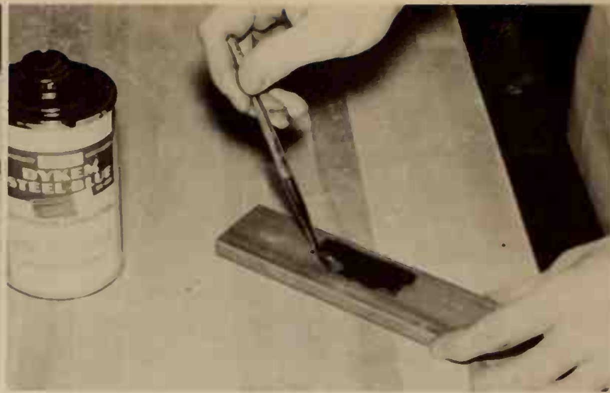


Fig. 4-13. Left, Marking a line across the stock with a combination square and a scriber. Fig. 4-14. Right, Applying layout fluid to piece of metal.

and width of the stock to serve as base lines from which all other layout lines can be accurately measured. If one edge of the material is even, it can be used as a base line.

6. Scribe all the straight lines first. Use center lines, or a true edge of the stock, to start all measurements.
7. Draw angular lines. Use the protractor head of the combination square set. It will be necessary to have one edge and one end true to

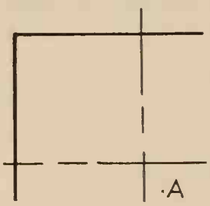


Fig. 4-15. Locating a center for laying out arcs and circles.

be used as a base for the straight edge of the protractor head.

8. Draw irregular lines. Following are two methods which may be used:
   (a) Use a template (pattern) of plywood or sheet metal. Place the template in place on the stock and trace around it with a scriber. This method is used when several pieces of the same shape are required.
   (b) Transfer design to metal using carbon paper. Apply a coat of showcard white to metal. Place a piece of carbon paper and then the design over the metal. Trace the design with a pencil or blunt tool.
9. Scribe all arcs and circles on the metal with the dividers. To locate the center for an arc, measure in the distance required and square the lines which intersect at point A, Fig. 4-15. Make a small indentation with a prick punch where the two main lines intersect at A. Use a rule to set dividers for the required radius, Fig. 4-16. Insert one point of

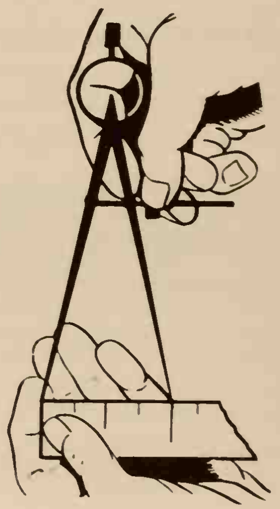


Fig. 4-16. Adjusting the dividers for a required radius.

the dividers in the center hole and, holding the stem by the thumb and forefinger, draw the arc or circle, Fig. 4-17.

10. Scribe lines on material to indicate all internal areas to be removed.
11. Lay out centers for holes. Locate all holes by measuring from two

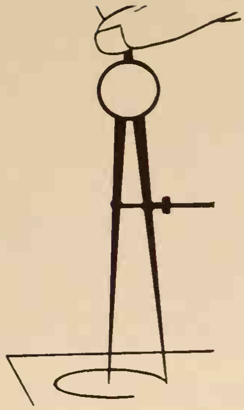


Fig. 4-17. Using the dividers to scribe a circle.

reference points and mark this area with two intersecting lines, Fig. 4-18. Make a small mark with a prick punch where these two lines intersect.

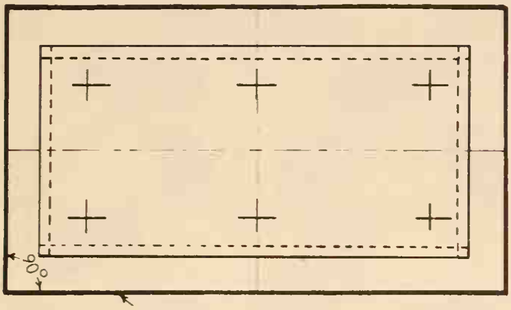


Fig. 4-18. Laying out location of holes to be drilled in stock.

CUTTING METAL

There are several tools and machines which can be used to cut ferrous and non-ferrous metals. The most common tools are the hack saw, cold chisel, bench shears, and power saw.

HACK SAWS

A hack saw has a blade, a U-shaped frame, and a handle, Fig. 4-19.

BLADES

To get the best results from a hack saw, it will be necessary for you to learn several facts about the different types of blades which are available so you can make a wise selection.

Size: Blades vary in length from 8 in. to 12 in., 1/2 in. wide, and 0.025 in. thick for general duty work, 5/8 in. wide, and 0.032 in. thick for heavy-duty work.

Fig. 4-19. An adjustable type hack saw frame. (Stanley Tools)

Material: Blades are made of high speed steel, tungsten alloy steel, molybdenum steel, and other special alloy steel.

Types: Only the teeth are hardened on a flexible-back blade. This type is considered best for the inexperienced worker, and makes a good all-around blade for general sawing. The all-hard type is hardened throughout the blade which makes them brittle and easy to break.

Teeth: The number of teeth on a blade range from 14 to 32 teeth per inch, Fig.

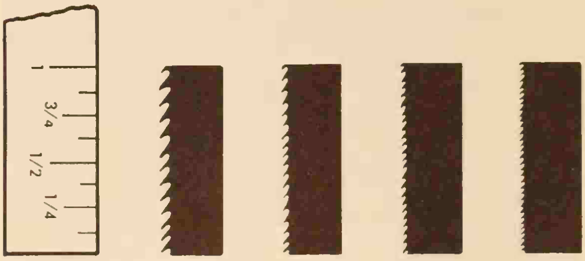


Fig. 4-20. Checking the number of teeth per inch.

4-20. Blades will last longer if you select one with the correct number of teeth for the job. Use a blade with 14 teeth for brass, aluminum, cast iron, and soft iron; 18 teeth for drill rod, mild steel, tool steel, and general work; 24 teeth for tubing, and pipe.

Set of teeth: This refers to the way the

teeth are bent. This provides proper clearance for the blade which makes the cutting easier and faster, and it prevents overheating the blade. Fig. 4-21, shows four general types of saw sets. The wave set is used for fine-tooth blades.

SAWING WITH HACK SAW

1. Select the correct blade, making sure that at least two teeth will be in contact with the metal at all times.

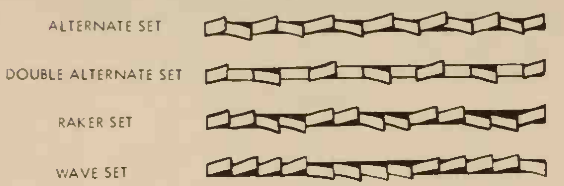


Fig. 4-21. Set of hack saw blade teeth.

2. Fasten the blade in the frame with the teeth pointing away from the handle. Tighten the blade with enough tension to hold it rigidly between the pins.
3. Secure the stock in a vise, or with clamps. The line where you are going to make the cut should be close to the end of the vise jaw or clamp, Fig. 4-22.

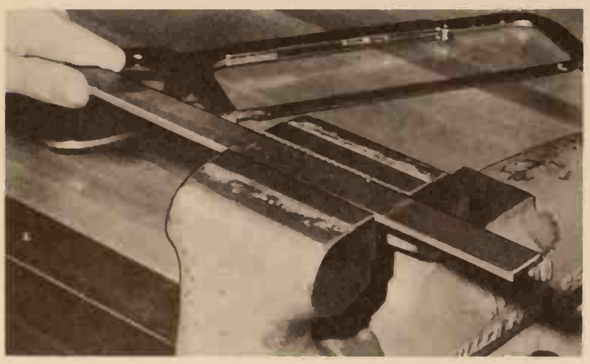


Fig. 4-22. Clamp stock tightly in vise. The line where the cut is to be made should be close to the vise jaws.

4. Hold the saw at the correct angle. Fig. 4-23 shows the right and wrong angles for cutting.
5. Start the cut with a light, steady forward stroke. At the end of each stroke, relieve the pressure and draw the blade straight back. After two or three strokes to get the cut started, take full-length strokes in a straight line. Do not allow saw to wobble. Hold the saw firmly with both hands. Continue sawing, using long steady strokes at a pace of 40 to 50 strokes per minute. Use just enough pressure on the forward stroke to make each tooth remove a small amount of metal, Fig. 4-24. Remember--do not use any pressure on the back stroke. Do not allow the teeth to drag over the metal.

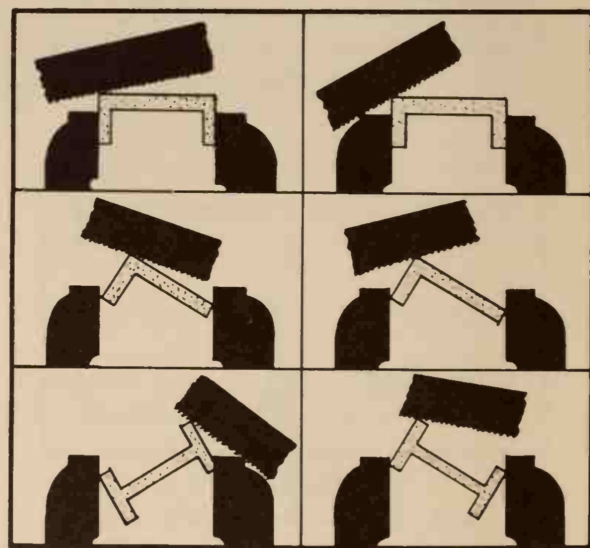


Fig. 4-23. Correct blade angle for starting cuts.

6. Slow down as you near the end of the cut so you can control the saw when the stock is sawed through.
7. To make a long cut along the side of a piece of metal, turn the blade at right angles to the frame. This makes it possible to saw a cut deeper than the saw frame would otherwise allow.

CHISELS

A chisel is a wedge-shaped tool used to shear, cut, and chip metal. When you can

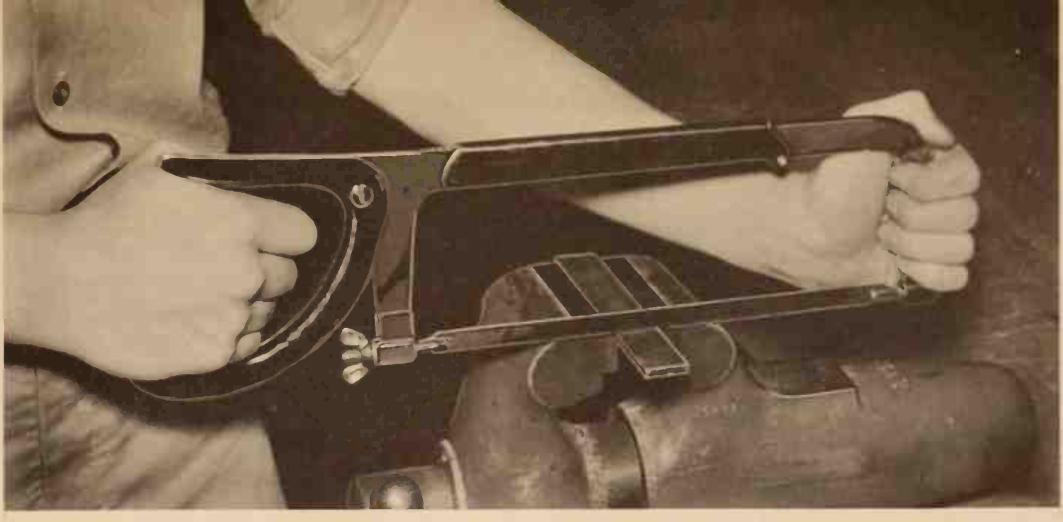


Fig. 4-24. Using hack saw. Apply pressure on forward stroke and release pressure on return stroke.

not use tin snips or a hack saw for cutting, reach for a chisel. It is your metal-cutting troubleshooter. It can be used in hard-to-get-to places for such jobs as shearing off rivets, smoothing castings, or splitting rusted nuts from bolts. A chisel will cut any metal that is softer than its own cutting edge, which is hardened and sharpened. There are four principal kinds of chisels used in bench metal work, Fig. 4-25.

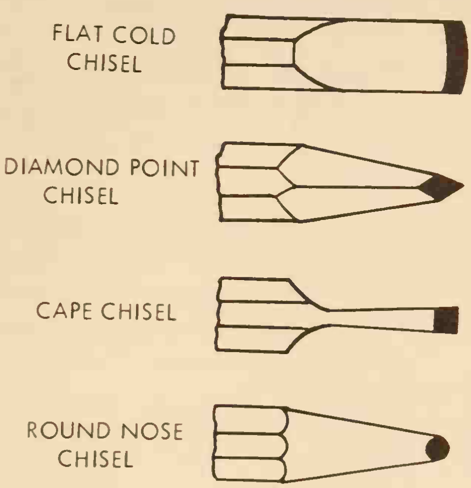


Fig. 4-25. Four kinds of chisels commonly used in metalwork.

1. Flat cold chisel - used for cutting, shearing, and chipping. The size is determined by the width of the cutting edge.
2. Cape chisel - used for cutting key-ways, square corners or slots.
3. Diamond point chisel - used for cutting V-grooves and inside sharp angles.
4. Round nose chisel - used to cut rounded or semi-circular grooves, corners which have fillets, and to "draw back" a drill which has "walked away" from its intended center.

You will use the flat cold chisel for most of your work. Keep your chisel sharp and ground at an angle of 60 to 70 deg. and the edge at a slight arc, Fig. 4-26. When grinding a chisel, hold it against the wheel

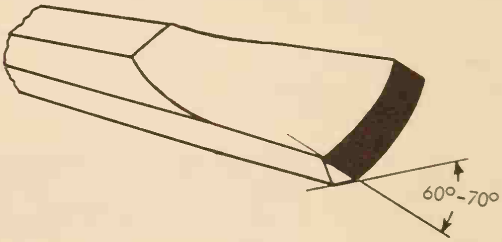


Fig. 4-26. The correct shape and point angle of a cold chisel.

with very little pressure to avoid over-heating. Dip the point in water often to keep it cool. If the point heats it will "draw" the temper of the steel. If this happens, the cutting edge will become soft and useless until it is rehardened and tempered.

Blows of the hammer will cause the head of the chisel to spread at the top like a mushroom. This is dangerous because

chunks of metal will break away from the overhanging mushroom with enough force to cause an injury. Always keep the head ground as in B, Fig. 4-27.

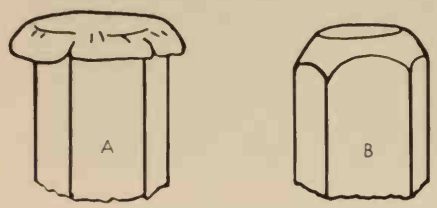


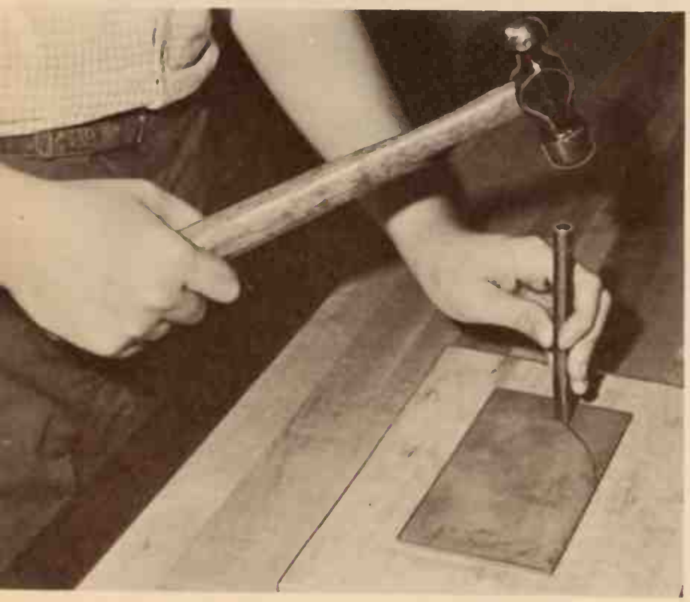
Fig. 4-27. Always keep the head of of chisels ground like "B."

CUTTING METAL WITH A COLD CHISEL

Following are two methods used to cut metal with a flat cold chisel:

A. Cutting over flat plate
   1. Scribe outline of pattern on metal.
   2. Place metal on top of a lead or soft steel back plate. Do not use finished surface of anvil, or vise.
   3. Grasp chisel in one hand, Fig. 4-28. Hold chisel in a perpendicular position with the cutting edge on the line to be cut.

Fig. 4-28. Cutting metal with a chisel.



   4. Strike the head of the chisel lightly with a ball-peen hammer. Keep your eyes focused on the line to be cut, not on the chisel. Move the chisel for the next cut. Check after each blow of the hammer to be sure the cutting edge of the chisel is on the outline to be cut.
   5. Continue the light cut until you have cut around the outline.

Fig. 4-29. Shearing metal.

   6. Place the chisel at the starting point and cut around the outline again. Use heavier blows this time.
   7. Continue cutting around outline until chisel is nearly through metal. Use lighter blows to finish cutting and to prevent cutting into the back plate.

B. Shearing in a vise.
   1. Clamp the metal securely in the vise with the line to be cut slightly above the top edge of the vise jaw.

SAMMY SAFETY
Says:

"Always wear safety glasses when cutting metal with a chisel."

2. Place the beveled surface of the chisel's cutting edge flat on the vise jaw, Fig. 4-29. The chisel will have a tendency to dig in if held too high. It will tear the metal and you will not get the proper cutting action if it is held too low.
3. Holding the chisel firmly and at an angle toward the work, direct

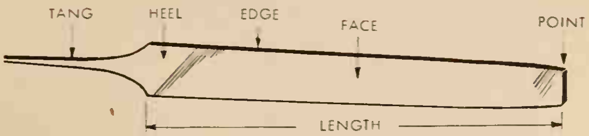


Fig. 4-30. Parts of a file.

the center of the cutting edge at the line to be cut so you will get a shearing action.
4. Start cutting at one end of the metal and strike the chisel hard enough to cut through the material. After each cut, advance the chisel until shearing is completed.

FILES

A file is a hard steel instrument made in various sizes, shapes, and cuts of teeth. Files are used for cutting, smoothing, and removing small amounts of metal. Fig. 4-30, shows the parts of a file. The three

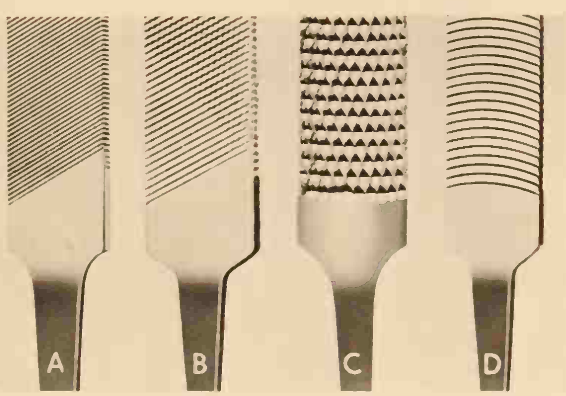


Fig. 4-31. Cuts of files: (A) Single cut; (B) Double cut; (C) Rasp cut; (D) Curved-tooth cut. (Nicholson File Co.)

distinguishing features of files are length, kind, and cut.

Length: The length of the file is the distance between the heel and the point. The tang which is made to hold the handle is not included in the length.

Kind (or name): This means the various shapes or styles which are called by such names as flat, mill, half-round, etc. These are divided according to the form of their cross-sections into three general geometrical classes--quadrangular (four-sided), circular, and triangular.

The cut: This refers to the character of the teeth such as single, double, rasp, and curved, Fig. 4-31, and also to the coarseness of the teeth, rough, coarse, bastard, second cut, smooth and dead smooth. Some

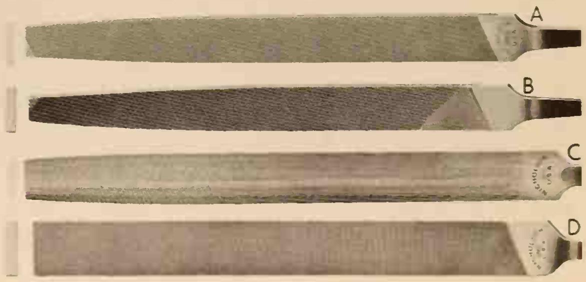


Fig. 4-32. Machinists' files: (A) Mill file; single cut, used for draw filing and finishing; (B) Flat file; double cut, for general work; (C) Half round file; double cut, used to file curved surfaces; (D) Hand bastard file; double cut, for finishing flat surfaces--it also has one safe edge (without teeth).

machinists' files used in the metal shop are shown in Fig. 4-32.

Selecting the correct file for the work to be done is very important, in order to obtain the greatest efficiency in filing. Many factors enter into the selection of the right file for the job.

1. Size of work: Use a large file on large work and a small file for small work.
2. Flat or convex surface: Use a flat-

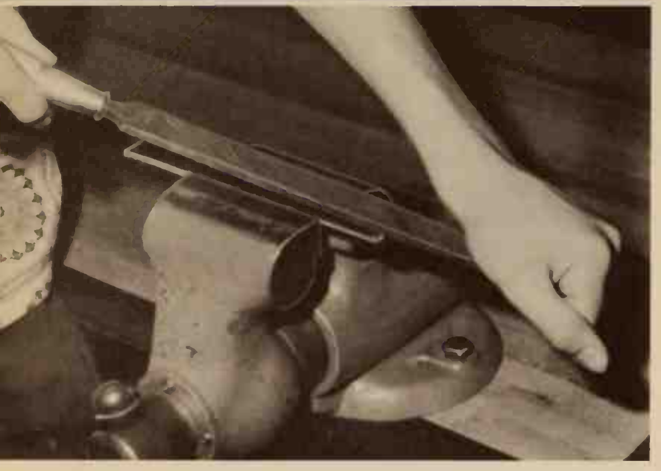


Fig. 4-33. Above, The proper way to hold a file for light filing. Fig. 4-34. Below, The proper way to hold a file for heavy filing.

shaped file for flat surfaces and a half-round or round-shaped file for curved surfaces.

3. Rough cutting: Use a coarse, double-cut file.
4. Square corners and enlarging square or rectangular openings: Use a square file.
5. Filing circular openings or curved surfaces: Use a round file.
6. Finishing a surface: Use a single-cut file in the second cut bastard, or a smooth file.
7. Hard steels: Use a second-cut file.
8. Soft steels: Use a bastard file.
9. Brass, aluminum, and lead: Use a special file, Fig. 4-31d.
10. Draw filing: Use a single-cut mill file.

FILING METAL

Filing is an art. The grip, pressure, and stroke must vary to fit the work being done and the kind of file used. Following are two methods for filing that you will use in bench metal work:

Straight filing. This method consists of pushing the file lengthwise--straight ahead or slightly diagonally--across the work.

1. Fasten the stock to be filed securely in a vise. The surface to be filed should be parallel to the vise jaws and a short distance above them to prevent "chattering" (excessive vibration).
2. Select the correct file for the job. For light and accurate filing, grasp the handle with one hand, allowing its end to fit into and up against the fleshy part of the palm below the joint of the little finger, with the thumb lying parallel along the top of the handle and the fingers pointing upward. Grasp the point of the file by the thumb and the first two fingers of the other hand, Fig. 4-33. For heavy work grasp the handle in the same manner just described. Place the palm of the hand on top of the point of the file with the fingers curled under, Fig. 4-34.
3. File the metal by "carrying" (stroke) the file forward on an almost straight line--changing its course often enough to prevent "grooving." A file cuts only on the forward stroke--release the pressure on the back stroke. Use a uniform stroking motion and keep the file flat on the work. Do not allow the file to "rock" as this will produce a rounded surface. Various metals require different touches, but in general, apply just enough pressure on the forward stroke to keep the file cutting at all times. If allowed to slide over hard metals the teeth will become dull.
4. Clean the file. The teeth become clogged with particles of metal. To

do a good job of filing, these filings or "chips" which collect between the teeth must be removed to keep the file working efficiently and prevent the "chips" from scratching your work. The teeth should be brushed frequently with a file card or brush, Fig. 4-35. Never strike your file against the bench or vise to clean it--

Fig. 4-35. Cleaning a file with a file card. Brush with the angle at which the teeth are cut.

the teeth are brittle and easily broken. When taking very fine cuts or in filing soft metals, such as copper and brass, rub the face of the file with chalk to prevent the teeth from becoming clogged.

5. Check the surfaces being filed for squareness. Hold the work up to the light and place a rule or square on the surface. If light shows between the surface being checked and the square, mark the high spots. File the

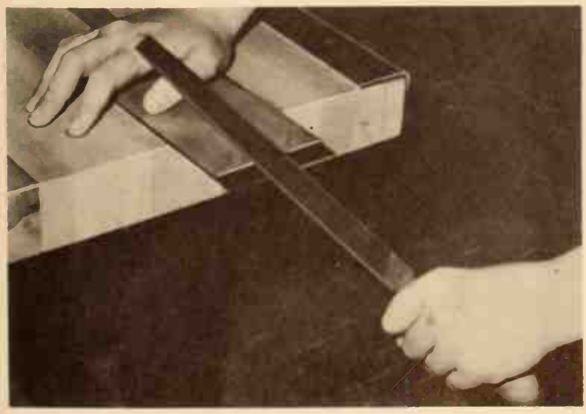


Fig. 4-36. Removing burrs from the edge of metal.

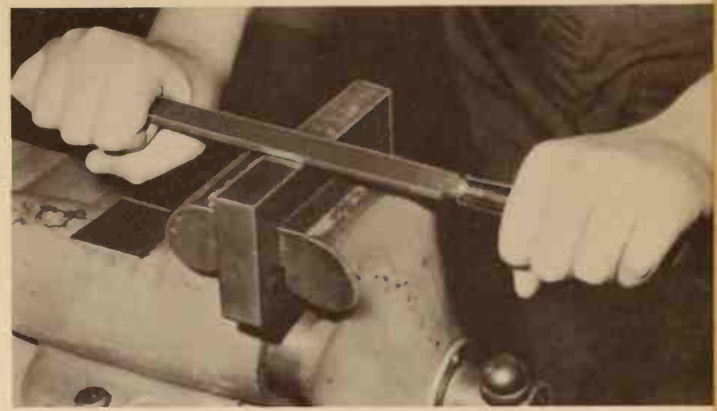


Fig. 4-37. Draw filing.

high spots lightly and check again. Continue this procedure until the stock is square.

6. Remove burrs from edges. When cutting or filing heavy sheet stock, burrs form on the edges. Remove these burrs by running the file across the sharp edges, Fig. 4-36.

<u>Draw filing.</u> This operation is performed by grasping the file at each end and pushing and drawing it across the work. A very smooth surface can be obtained by this method. Generally a mill bastard file is used for draw filing.

1. Grasp the file firmly at each end and place the file on the work at the end away from you.
2. Holding the file steady, apply sufficient pressure to get a cutting action, and draw file toward you, Fig. 4-37. At the end of each stroke lift the file and return to the starting point. Use a new section of the file for each stroke. After one side of the file has been used up turn it over and use the other side. After both sides have been used, clean the file before repeating the process. This is important because a chip between the teeth will scratch the filed surface.

Protect your files by observing these rules:

1. Always keep a good handle on your

file. The tang has a sharp point which can pierce your hand. Never use a file without a handle.

2. Never use a new file to remove scale from metal. Use an old, worn file for this job.
3. Avoid getting files oily. Oil causes a file to slide across the work and prevents fast, clean cutting.
4. Protect the file teeth. Always hang files in a rack when not in use. Never allow the teeth to come in contact with other files or tools. If you put a file in a toolbox or drawer with other tools, wrap the file with cloth.
5. Keep the file clean. Use a file card to clean the file after every few strokes. Sometimes it is necessary to use a sharp pointed nail or piece of wire to remove stubborn "chips."
6. Never use a file for prying or pounding. The body of a file is hard and very brittle. A slight bend or a fall to the floor might cause the file to break in two.
7. Never hammer on a file. Since it is hard and extremely brittle the blows might cause sharp chips to fly in all directions and injure someone.

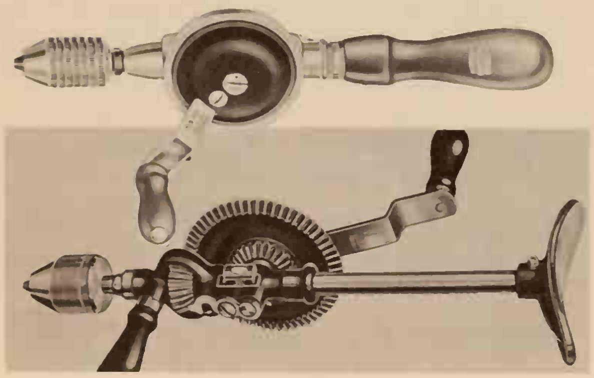


Fig. 4-38. Above. Hand drill; Below. Breast drill. (Stanley Tools)

CUTTING HOLES IN METAL

One way to produce holes in solid metal is to use a drill. Holes up to 1/2 in. in diameter can be drilled by hand with a hand or breast drill, Fig. 4-38. A portable electric drill is also a very useful and fast tool for drilling holes in metal. When drilling holes larger than 1/2 in. in diameter use a drill press, Fig. 4-39.

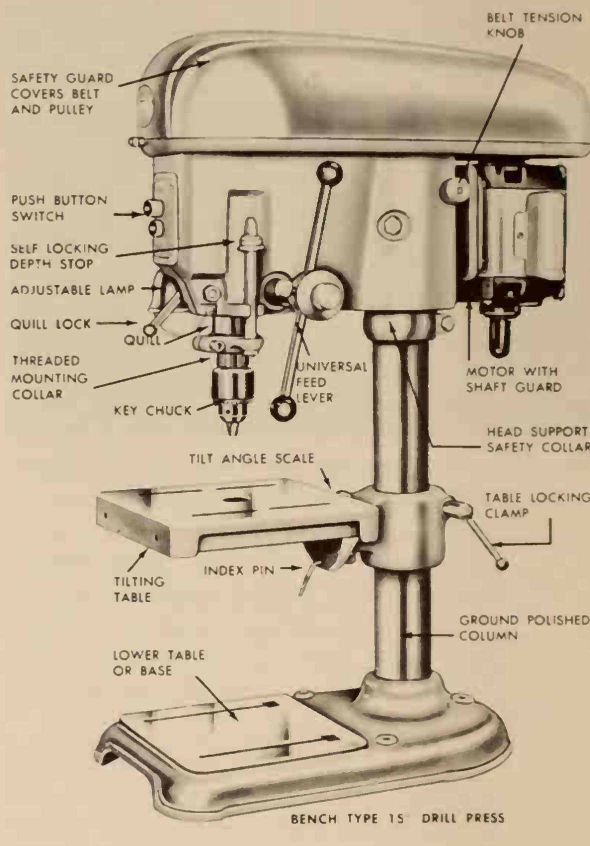


Fig. 4-39. A drill press.

The actual cutting of holes is done with a twist drill. A drill has three main parts, the shank, the body, and the point, Fig. 4-40. The shank end fits into the chuck or spindle of the drilling machine. The most commonly used twist drills are made of carbon steel and high speed alloy steel. The two types of shanks most commonly used are the straight and taper, Fig. 4-41. The body of the drill is the section extending from the shank to the point. The two spiral grooves running around the body are called flutes. The point of the drill which does the cutting is the "business end" of the drill. The point is formed

by the ends of the web, flutes, and margins of the drill body. The two sharp edges that do the cutting are called lips. The lips must be sharp and properly ground to do an efficient job of cutting.

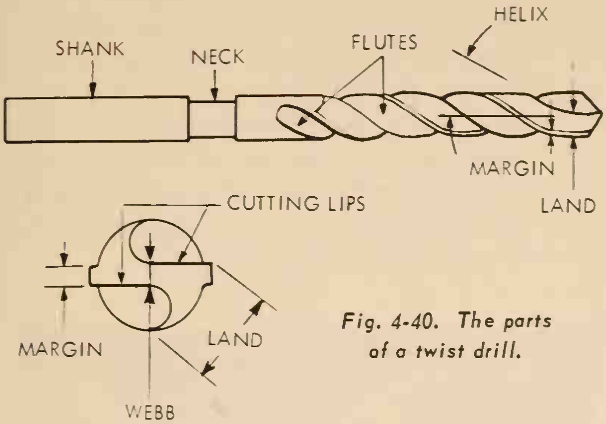


Fig. 4-40. The parts of a twist drill.

The twist drills you will use most frequently are those made in fractional sizes which start at 1/64 in. and go to 1 in. in diameter. The size is stamped on the shank of the drill. If the size number has worn off the drill shank, you can check the size with a Drill Gauge, Fig. 4-42. Because these drills vary 1/64 in. from

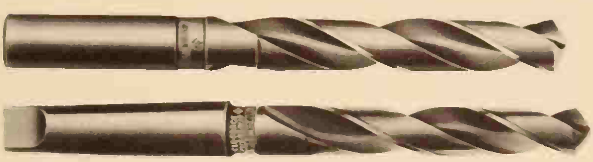


Fig. 4-41. Two types of drill shanks. Above. Straight shank. Below. Taper shank. (Cleveland Twist Drill Co.)

one size to the next, two other systems have been developed to provide in between sizes. Number drills range from No. 80 to No. 1, and letter drills range from A to Z. Fig. 4-43, shows these drill sizes and their decimal equivalent.

There are five things that must be checked when grinding a drill:

1. Lip angle. For most work the two

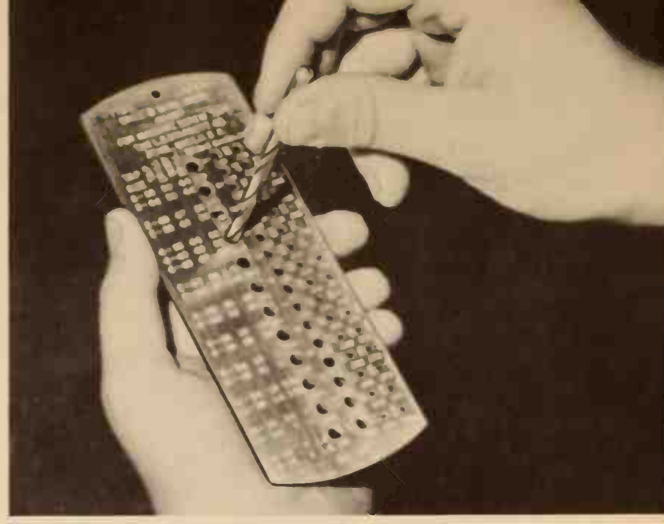


Fig. 4-42. Checking the size of a drill with a drill gauge.

Number Drills	Fractional Drills	Decimal Equiv.	Number Drills	Letter Drills	Fractional Drills	Decimal Equiv.	Letter Drills	Fractional Drills	Decimal Equiv.
80	...	.0135			1/8	.1250	O	....	.3160
79	...	.0145	30		....	.1285	P	....	.3230
	1/64	.0156	29		....	.1360		21/64	.3281
78	...	.0160	28		....	.1405	Q	....	.3320
77	...	.0180			9/64	.1406	R	....	.3390
76	...	.0200	27		....	.1440		11/32	.3437
75	...	.0210	26		....	.1470	S	....	.3480
74	...	.0225	25		....	.1495	T	....	.3580
73	...	.0240	24		....	.1520		23/64	.3594
72	...	.0250	23		....	.1540	U	....	.3680
71	...	.0260			5/32	.1562		3/8	.3750
70	...	.0280	22		....	.1570	V	....	.3770
69	...	.0292	21		....	.1590	W	....	.3860
68	...	.0310	20		....	.1610		25/64	.3906
	1/32	.0312	19		....	.1660	X	....	.3970
67	...	.0320	18		....	.1695	Y	....	.4040
66	...	.0330			11/64	.1719		13/32	.4062
65	...	.0350	17		....	.1720	Z	....	.4130
64	...	.0360	16		....	.1770		27/64	.4219
63	...	.0370	15		....	.1800		7/16	.4375
62	...	.0380	14		....	.1820		29/64	.4531
61	...	.0390	13		....	.1850		15/32	.4687
60	...	.0400			3/16	.1875		31/64	.4844
59	...	.0410	12		....	.1890		1/2	.5000
58	...	.0420	11		....	.1910		33/64	.5156
57	...	.0430	10		....	.1935		17/32	.5312
56	...	.0465	9		....	.1960		35/64	.5469
	3/64	.0469	8		....	.1990		9/16	.5625
55	...	.0520	7		....	.2010		37/64	.5781
54	...	.0550			13/64	.2031		19/32	.5937
53	...	.0595	6		....	.2040		39/64	.6094
	1/16	.0625	5		....	.2055		5/8	.6250
52	...	.0635	4		....	.2090		41/64	.6406
51	...	.0670	3		....	.2130		21/32	.6562
50	...	.0700			7/32	.2187		43/64	.6719
49	...	.0730	2		....	.2210		11/16	.6675
48	...	.0760	1		....	.2280		45/64	.7031
	5/64	.0781		A	....	.2340		23/32	.7187
47	...	.0785			15/64	.2344		47/64	.7344
46	...	.0810		B	....	.2380		3/4	.7500
45	...	.0820		C	....	.2420		49/64	.7656
44	...	.0860		D	....	.2460		25/32	.7812
43	...	[illegible]		E	....	.2500		51/64	.7969
42	...	.0935			1/4	.2500		13/16	.8125
	3/32	.0937		F	....	.2570		53/64	.8281
41	...	[illegible]		G	....	.2610		27/32	.8437
40	...	[illegible]			17/64	.2656		55/64	.8594
39	...	[illegible]		H	....	.2660		7/8	[illegible]
38	...	.1015		I	....	.2720		57/64	[illegible]
37	...	.1040		J	....	.2770		29/32	.9062
36	...	.1065		K	....	.2810		59/64	.9219
	7/64	.1094			9/32	.2812		15/16	[illegible]
35	...	.1100		L	....	[illegible]		61/64	[illegible]
34	...	.1110		M	....	[illegible]		31/32	[illegible]
33	...	.1130			19/64	[illegible]		63/64	.9844
32	...	.1160		N	....	.3020		1	1.0000
31	...	.1200			5/16	.3125			

Fig. 4-43. Drill sizes and their decimal equivalents.

lips should form an angle of 59 degrees, Fig. 4-44.

2. Lip length. Both cutting edges (lips) must be the same length. Fig. 4-44. If the lips are of unequal length the drill will cut oversize.

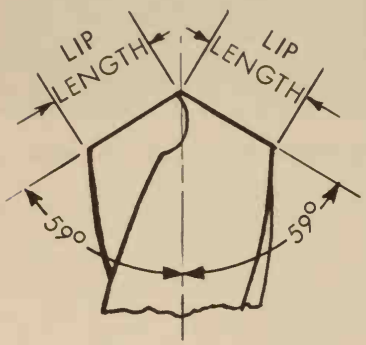


Fig. 4-44. Correctly ground drill lips.

3. Lip clearance. Only the cutting edge of the two lips should contact the metal being drilled. The surface behind the cutting edge of each lip must be ground back at an angle of 12 deg. to provide proper clearance, Fig. 4-45. This angle can be increased to

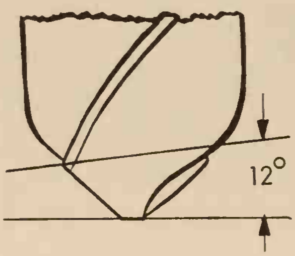


Fig. 4-45. Angle of lip clearance.

15 deg. for heavy feeds in soft metals.

4. Lip sharpness. The drill will not cut properly if the lips are rounded and dull, or chipped and burned.
5. Full margin. The distance from margin-to-margin determines the diameter of the drill. If the margin is worn away or broken, the drill will heat excessively and cut a tapered, undersize hole.

PROCEDURE FOR GRINDING A DRILL

Note: Practice the first two steps without turning on the grinder to get the "feel" of the angles and movements required to grind the drill properly:

1. Hold the drill near the point with your left forefinger and thumb. Cradle the drill in the first joint of your forefinger and place the back of your finger on the tool rest. Grasp the drill shank with your right thumb and forefinger. Keep the drill shank to the left, and move the point forward so that one lip comes in contact with the grinding wheel, Fig. 4-46.

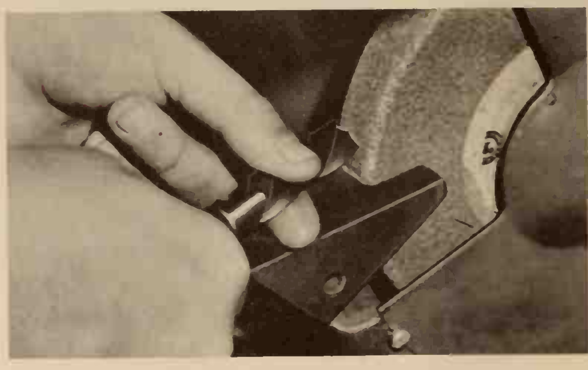


Fig. 4-46. The correct way to hold a drill for grinding.

2. Keep the shank slightly lower than the point. As the lip contacts the wheel, push down on the drill shank so that the heel (back of the lip) of the drill is moved along the grinding wheel face. When the back edge of the heel surface is reached, the drill should be pulled away from the grinding wheel.
3. After you have practiced steps 1 and 2 a few times, turn on the grinder switch. Start grinding the drill, removing very little metal at first. Try to maintain the original shape of the point. Move the drill steadily and evenly, maintaining uniform pressure against the wheel as you grind. Check your work frequently with a drill-point gauge to be sure that you have the proper lip clearance of 12 deg., the proper lip angle of 59 deg., and that the two lips are the same

length, Fig. 4-47. Do not allow the drill to overheat while sharpening. Drills can be cooled in water. Cool high-speed drills in the air otherwise they might crack.

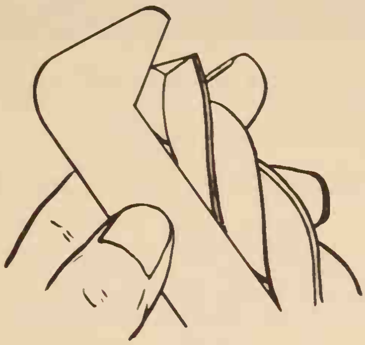


Fig. 4-47. Checking the point with a drill grinding gauge.

DRILLING BY HAND

The hand drill is used to drill holes 1/4 inch in diameter or smaller. Its "big brother," the breast drill, is designed for tougher jobs and will drill holes up to 1/2 inch in diameter. Following is the procedure for using hand and breast drills:

1. Center punch hole locations as indicated by the prick punch marks which were made during the layout operation, Fig. 4-48. Make the opening with the center punch large enough to receive the point of the drill.

Fig. 4-48. Using a center punch.

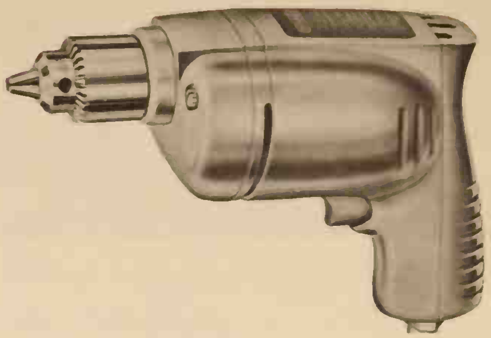


Fig. 4-49. A portable electric hand drill. (Stanley Tools)

2. Select the correct size drill. To insert drill in the chuck, grip the crank handle and body of the hand drill tightly with one hand. Use the other hand to turn the chuck shell to open the jaws wide enough to allow the drill shank you are going to use to enter. Tighten the jaws of the chuck so the drill is held firmly.
3. Secure material to be drilled in a vise or clamp it to a bench, if possible, clamp piece in a position so drilling can be done horizontally. Place the point of the drill in the center punch opening and crank drill at a moderate speed, making sure that you hold it at the proper angle with the work, usually 90 deg. Hold the drill steady, and apply enough pressure to keep the point cutting.
4. When the drill point is about to break through the metal, ease up on the pressure. Should the drill catch or jam in the material, finish cutting the hole by turning the chuck by hand. The drill should not be allowed to project through the hole any farther than is necessary to complete the hole. When the hole is completed, remove the drill. Continue to turn the drill in a clockwise direction and pull back on the handle.

DRILLING WITH PORTABLE POWER DRILL

The portable electric drill, Fig. 4-49, is

Fig. 4-50. Left, Using an electric hand drill. Fig. 4-51. Right, Inserting a drill in the drill press chuck.

used the same way as a hand drill, except that you do not have to crank it. Portable electric drills vary in size. The two most common sizes have a rated capacity of 1/4 in. and 1/2 in. in steel. To drill holes with a portable electric drill:

1. Place work in a vise or clamp it to the bench. The drilling can be done either horizontally or vertically.
2. Insert proper size drill bit for the job into drill chuck. Tighten the jaws against the drill bit with the chuck key.
3. With the power off, place the point of the drill in the center punch opening.
4. Hold the drill with one hand and steady it with the other. Turn on the power and apply steady pressure, Fig. 4-50.
5. When the drill point is about to break through the material, ease up on the pressure. Remove the drill from the hole and turn off the power. Do not allow the drill bit to jerk or bind since this will probably cause it to break off.

DRILLING WITH A DRILL PRESS

The drill press automatically holds and rotates the drill bit at the proper angle with the work. Drill presses vary in sizes ranging from small bench models to huge multiple-spindle types. When you use a drill press follow this procedure:

1. Locate the center of the hole to be drilled and mark the hole with a prick punch.
2. Enlarge the hole with a center punch.
3. Select the correct size drill and insert the drill in the chuck. Tighten the drill with the chuck key, Fig. 4-51.
4. Clamp the work to the table of the drill press. The type of clamp or jig used will depend on the nature of the job. Adjust the work so the point of the drill is lined up with the center mark. Place the drill press table at the correct height for the job. Check to see that the drill bit will pass through a clearance hole or slot in the table

Fig. 4-52. Holding work while drilling. Left, Holding work with a monkey wrench. Center, Using a pair of pliers to hold thin stock. Right, Pieces clamped in drill press vise.

and there is no danger of drilling into the table. Fig. 4-52 shows several ways to hold metal while it is being drilled.

5. Adjust the drill press for the correct speed. The speed for drilling holes varies with the size of drill bit and material being used. The larger the drill bit, the slower the speed. A slow speed is used for hard metals and a higher speed for soft metals.

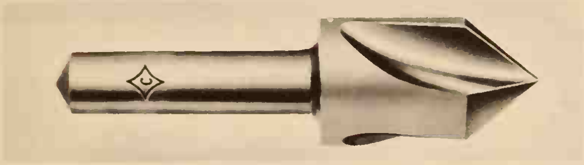


Fig. 4-53. A countersink drill. (Cleveland Twist Drill Co.)

6. Turn on the power and bring the drill point down to the piece slowly. Feed the drill into the center mark with a steady, even pressure. Apply cutting fluid often enough during drilling operation to keep the drill bit lubricated and from becoming too hot.
7. Reduce the pressure slightly when the drill bit begins to go through the bottom side of the piece. This will help prevent the drill from catching.

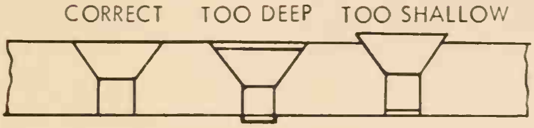


Fig. 4-54. The correct and incorrect way to countersink a hole.

8. When drilling holes larger than 3/8 in. it is good practice to drill a small pilot hole first. The diameter of the pilot hole, which is sometimes called a lead hole, should be approximately the size of the web thickness of the larger drill.
9. Holes which are to receive tapered heads of rivets, screws; or bolts, must be countersunk. This may be done with a countersink drill, Fig. 4-53, or by using a drill bit twice the diameter of the hole. Countersink the hole enough to allow the head of the rivet, screw, or bolt to fit flush with the surface of the metal, Fig. 4-54.

BENDING, FORMING, AND TWISTING METAL

Some of your projects will require the bending of metal at right angles, acute angles, and obtuse angles. Other pieces of your project may require scroll work or the twisting of some of the parts. Most of the ferrous and nonferrous metals 1/4 in. or less in thickness can be bent cold. To make angular bends follow this procedure:

1. Make a full-size layout of the part to be bent, so you can determine the amount of metal to allow for the bends. To make a right-angle bend, add an amount equal to one-half the thickness of the metal for each bend. For example, if you are using 1/8-in. thick material, and you are going to make two right-angle bends, add 1/8 in. to the length of material, Fig. 4-55.

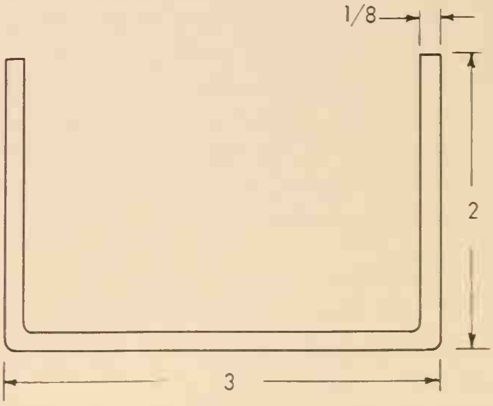


Fig. 4-55. Allow one-half the thickness of the metal for each bend.

2. When more than one bend is to be

made, decide on the order of bending, so you can determine where to make the allowances for bending, in the layout. This is necessary because the extra amount added to the length of the material for bending, should always be placed above the vise jaws when making the bend. Fig. 4-56.

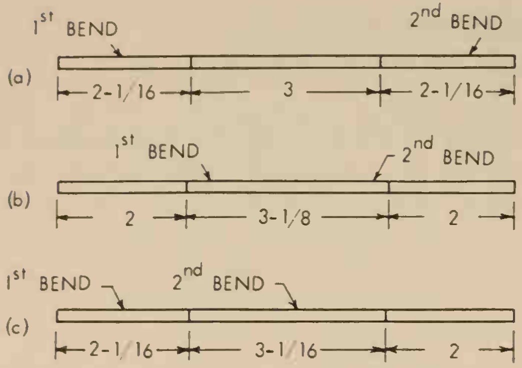


Fig. 4-56. Allowances laid out for the order of bending. The allowance has been added to the section that is to undergo the actual bending.

3. Clamp the metal in the vise with the bend line at the top of the jaws, with the allowance end above the jaws, Fig. 4-57. Check the material with a square to make sure it is straight.
4. Bend the metal by applying pressure with one hand, and striking the metal near the jaws of the vise with a hammer at the same time, Fig. 4-58. Strike the metal just hard enough to complete the bend.

Fig. 4-58. Bending metal in a vise.

5. Check the bend with a square to make sure the bend is accurate.
6. To make a bend that is greater than 90 degrees (obtuse angle) use a monkey wrench, Fig. 4-59. It is not necessary to make any allowance for very shallow bends. If the bend is

Fig. 4-59. Making a bend that is greater than 90 deg.

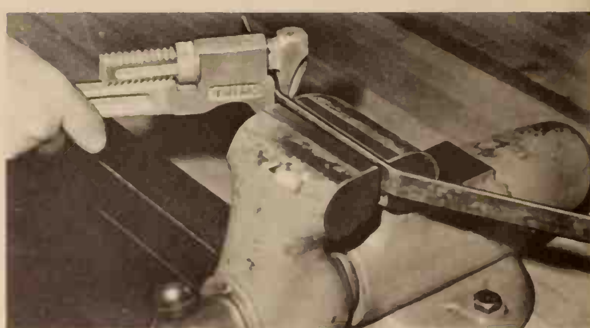
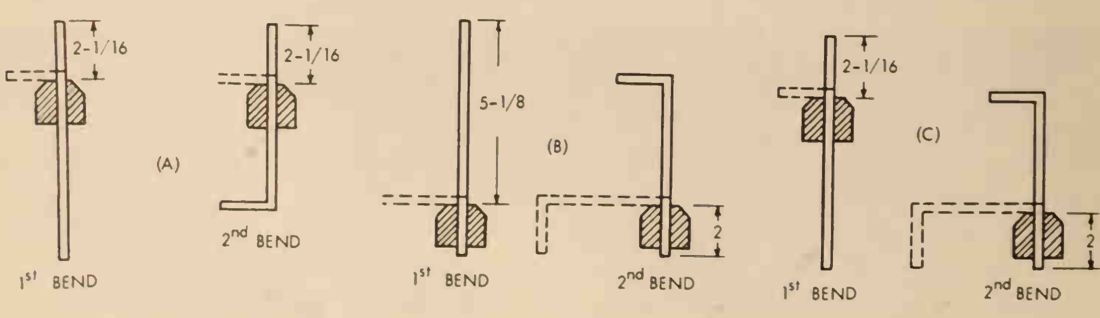


Fig. 4-57. The order of bending layouts which are shown in (A), (B), and (C), Fig. 4-56.



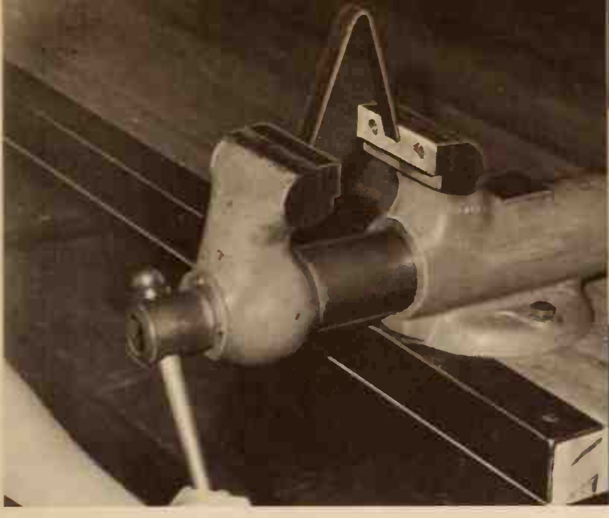


Fig. 4-60. Left, Making a bend that is less than 90 deg. Fig. 4-61. Right, Forming a circular bend over a rod.

close to a right angle, an allowance should be made.

7. To make a bend that is less than 90 degrees (acute angle) the same allowance as made for a right angle bend must be made. Follow the procedure for making a right-angle bend. To obtain the sharp angle, place the right angle bend between the jaws of the vise, and squeeze the two sides together until the correct angle is obtained, Fig. 4-60.

BENDING CURVES

Many projects require circular bends. This type of bending can be done by forming the metal around a rod or pipe, or with

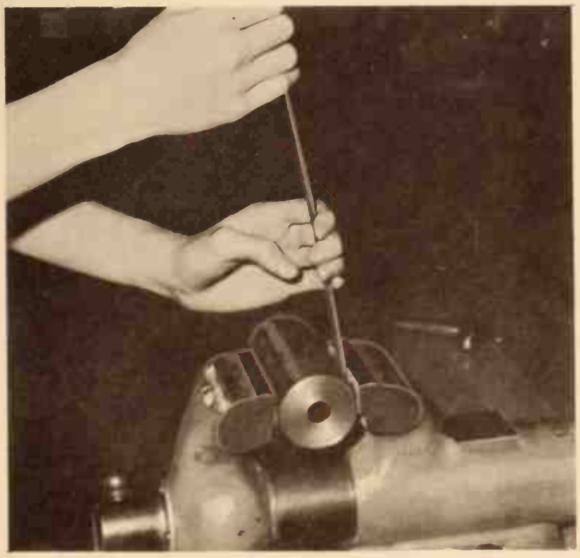


Fig. 4-62. Fasten both the rod and the work in the vise. Draw the work around the rod.

bending and forming machines. Most metal 1/4 in. or less can be formed cold.

To form circular bends, clamp a rod or piece of pipe in a vise. Place the metal over this piece, in the vise. Strike the metal glancing blows with a ball-peen hammer, Fig. 4-61. Move the metal forward gradually, striking the metal until the desired curve is formed.

Another method that may be used when a certain radius or diameter circle is to be formed is to clamp a piece of pipe or rod equal to the inside diameter of the circle or radius in a vise, with the piece of stock to be bent clamped between the rod or pipe and the solid jaw of the vise, Fig. 4-62. Grasp the end of the stock extending above the vise jaws, and pull the metal down against the bending device. Loosen the vise jaws and feed the stock in around the rod, and clamp in place as before. Continue this procedure until the desired circle or radius has been formed. Metal that is too thick to be formed by hand can be bent around the bending device by pulling it with one hand and striking it close to the bending device with a ball-peen hammer. Continue the bending operation by feeding the metal around the bending device and hammering it down against the bending device until the desired circle or radius is obtained.

A small eye can be formed by clamping the stock to be bent, and a piece of cylindrical pipe or rod equal to the inside

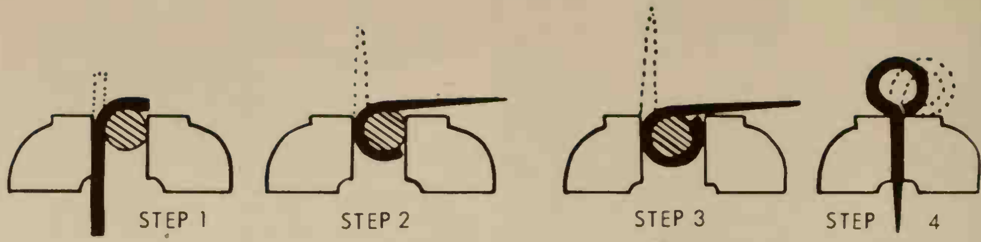


Fig. 4-63. Steps in forming an eye.

diameter of the eye, in a vise. Follow the steps shown in Fig. 4-63.

TWISTING METAL

Very interesting and pleasing lines can be added to parts of a metal project by twisting some of the pieces. Twisting is also used to give additional strength and to change the position of the piece so it can be fastened at the ends. Mild steel band iron 1/4 in. or less in thickness and 1-1/2 in. or less in width, can be bent cold. Square rods of mild steel up to 1/2 in. can be bent without heating. To bend larger sizes of

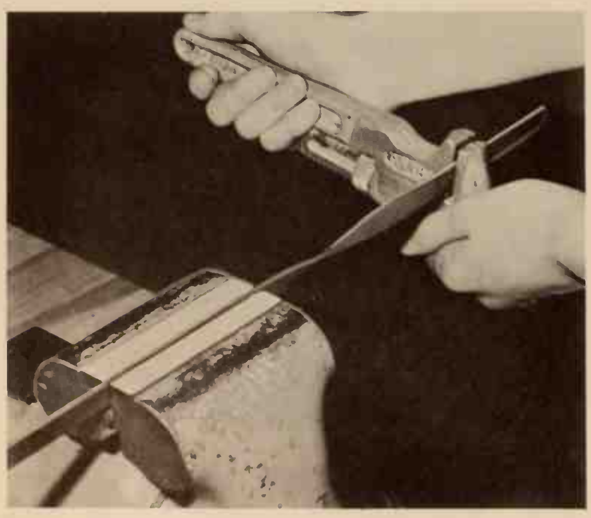


Fig. 4-64. Twisting metal with a wrench.

stock, heat the metal to a dull red color in a forge or with a torch.

The procedure for twisting metal is:

1. Determine the portion of the stock to be twisted, and the number of desired twists. Calculate the amount of stock to allow for twisting (which tends to shorten stock) by taking a scrap piece of metal the same kind to be twisted and check the length. Make a single twist in this test piece and check the length. The difference between the length before, and after twisting, is the amount to allow for each twist to be made.
2. Mark off the section of the metal to be twisted. If duplicate pieces are to be made, mark them at the same time.
3. Place the metal to be twisted in a vise with one of the limit marks for the section to be twisted even with the outer edge of the vise jaw. Short pieces should be clamped in a vertical position, and long pieces should be clamped in a horizontal position. Clamp a monkey wrench at the other end of the section to be twisted, Fig. 4-64. The twist may be made to the right or left. Rotate the wrench until the desired number of twists have been obtained.
4. When twisting a long piece of metal,

Fig. 4-65. Straightening metal after twisting.

it is sometimes difficult to keep it straight. This can be corrected to some extent by slipping a piece of pipe which is slightly larger than the metal, over the section to be twisted.
5. If the piece of metal needs straightening after being twisted, place it

over a hardwood block and hammer it with a wood or lead mallet, Fig. 4-65. Do not strike the metal hard enough to damage the twist. Rotate the metal as you straighten it so the portion not touching the surface of the board can be brought in line with the surface of the board. Continue this procedure until the metal is straight.

FORMING A SCROLL

A scroll is a piece of metal which has been bent to a circular shape to form a spiral similar to the shape that would be formed if a clock spring were spread open, Fig. 4-66. Scroll work is used mainly for decorative purposes. When properly used,

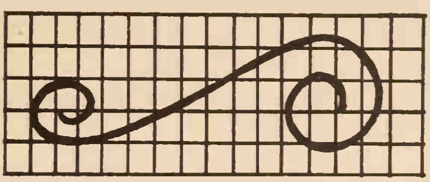


Fig. 4-66. A scroll.

scrolls break up the monotony of straight lines and add interesting features to projects. Scrolls may be formed by using jigs, forks, and other devices.

The procedure for forming a scroll is:

1. Lay out a full-size pattern of the desired scroll on a piece of heavy wrapping paper or cardboard. This pattern is used to help determine the length of stock needed and to check the work as the bending proceeds.
2. Determine the length of stock that will be needed for the scroll by forming a piece of soft wire or stock on the pattern. Then straighten the wire and measure its length.
3. Cut the stock to the correct length. Decorate the surface and the ends of the stock as desired. See Fig. 4-74, and Fig. 4-75. Select the bending device and clamp it in a vise or to a bench, Fig. 4-67.
4. Start forming the scroll by grasping the end of the metal with one hand, placing the other end in the bending device and holding it in place with the other hand, Fig. 4-68. Apply pressure with the thumb of the hand at the bending jig. Use the other hand to pull the metal against the bending jig with enough pressure to start

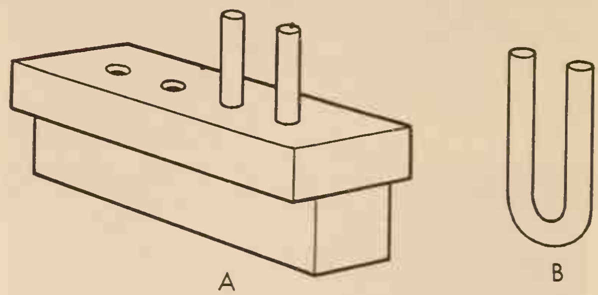
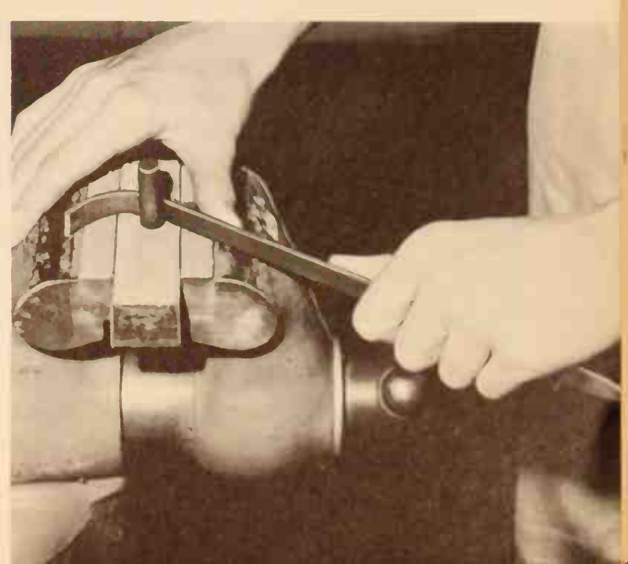
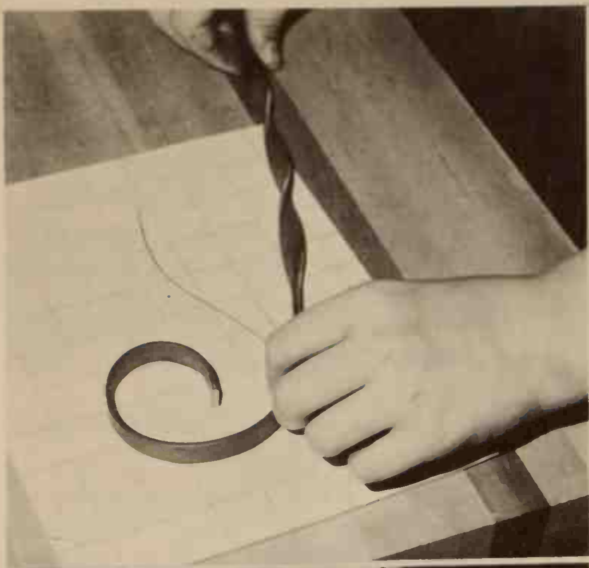


Fig. 4-67. Scroll bending devices. Left. Metal block with pins that can be adjusted for different thicknesses of metal. Right. U-shaped bending fork made from a rod.

forming the scroll. Move the metal into the jig a little at a time and continue to apply even pressure. This allows the scroll to form evenly and gradually without sharp bends. Most beginners have trouble forming scrolls without sharp bends because they try to form too much between each application of pressure. By developing a rhythm of sliding the metal through the jig (not over 1/8 in.

Fig. 4-68. Forming a scroll by hand.





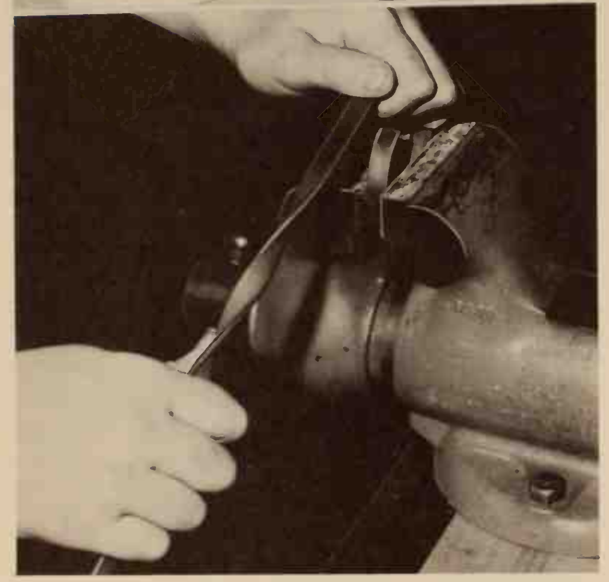


Fig. 4-69. Above, Checking scroll on a full-size pattern.
Fig. 4-70. Below, Straightening scroll so it will lie flat.

at a time) and applying pressure to the metal at the jig each time the metal is moved forward, smooth curves can be produced without kinks. Form a small section of the scroll and check it by placing the piece on the full-size pattern, Fig. 4-69. Complete this section of the scroll before moving on to the next part of the scroll to be formed. If the curve of the scroll needs to be corrected, it can be opened by placing the metal back in the jig and applying pressure in the opposite direction. Be sure to do this gradually, moving metal through the jig a little at a time. Continue to form the metal and check often until the scroll fits the pattern.

5. When the scroll has been completely formed, check it to see if it will lie flat. If the scroll needs to be straightened, place it in a vise edgewise and straighten it by hand. Fig. 4-70.

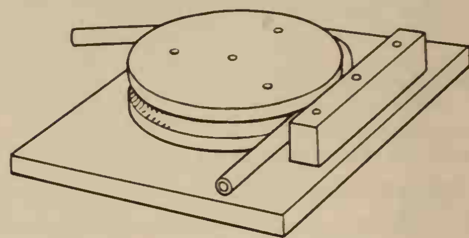


Fig. 4-71. Jig for bending pipe and tubing.

BENDING SMALL PIPE AND TUBING

Pipe and tubing can be formed successfully by using a jig, Fig. 4-71. If a sharp bend is necessary, fill the pipe or tubing with wet sand or molten lead. This will prevent the pipe or tubing from collapsing while being formed. Place the pipe or tubing in the jig and slowly draw it around the form. Remove the sand or lead after the desired shape has been formed.

BENDING AND FORMING MACHINES

There are several machines available for bending and forming metal accurately and smoothly. Fig. 4-72, shows a No. 2 Di-Acro bending machine which can be used to form flats, rods, tubing, channel, and angle. Fig. 4-73, shows the bender being used to make various bends.

SAMMY SAFETY *Says:*

"When filling a pipe or piece of tubing with molten lead, be sure it is completely dry. Moisture causes molten metal to splatter and it might cause a serious accident."

DECORATING ENDS OF METAL

The ends of band iron can be made attractive and their appearance improved by grinding, filing, cutting, or hammering. Some possible shapes are shown in Fig. 4-74. To make a shape like (b), first lay out the design on the end of the metal.

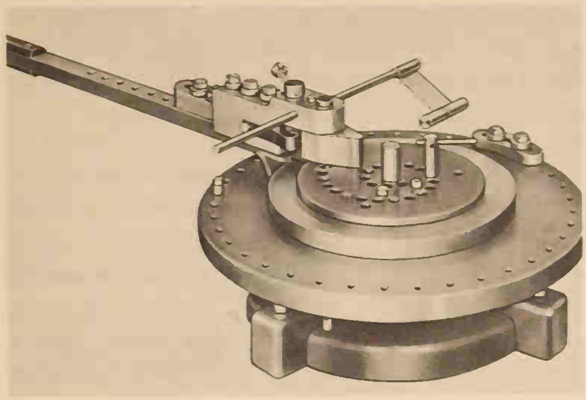


Fig. 4-72. A No. 2 Di-Acro bending machine. (Irwin O'Neil Mfg. Co.)

Spread the end of metal into a fan shape (indicated by dotted lines) by placing the

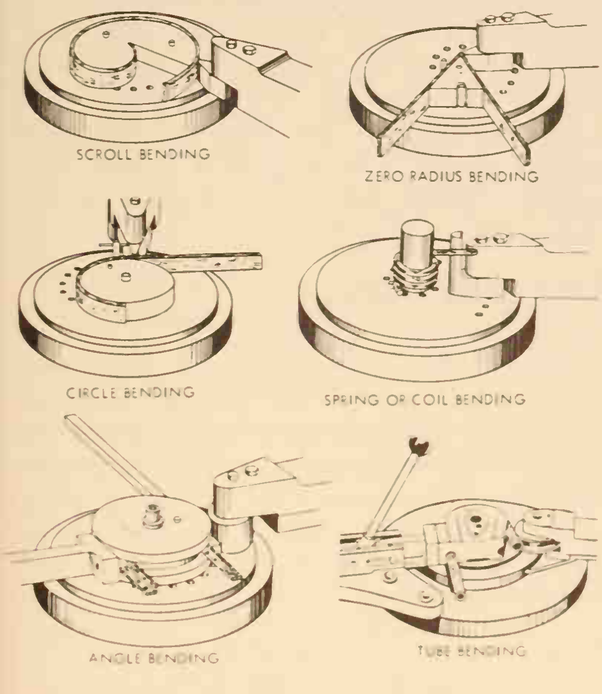


Fig. 4-73. Some bends that can be made on Di-Acro bending machine.

end of the metal near the edge of an anvil and by striking the metal with a ball-peen hammer. Continue striking the end of the metal, working from edge to edge with closely spaced blows until the end takes a fan shape. Grind the end to a pointed shape. Finish the ground edges of the metal by hammering them down to a thin edge so the metal tapers evenly from the center of the design out to the edges and the point. If the edges of the design on the end of the metal are a little uneven, true them up with a file. Hammer the edges again with very light blows to remove any indications

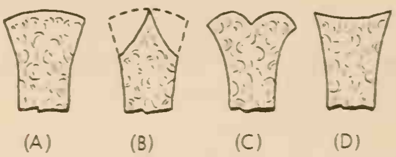


Fig. 4-74. Suggested end designs for band iron. (A) Fan shaped; (B) Arrow head; (C) Fish tail; (D) Flared.

of file marks. In addition to the surface texture obtained with a ball-peen hammer, other very interesting effects can be secured on the ends of the metal by using a cross-peen or straight-peen hammer.

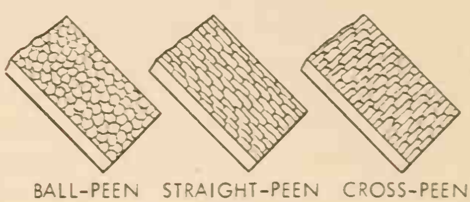


Fig. 4-75. Suggested surface decorations for band iron.

DECORATING THE SURFACE OF METAL

Many interesting and decorative textures can be produced on the surface of metal by hammering it with a ball-peen, cross-peen, or straight-peen hammer. The effect can also be varied by using different size hammers and controlling the force of the blow.

To decorate the surface, mark the area

of the metal to be peened or hammered. Select the hammer that will produce the desired texture, Fig. 4-75. Holding the metal with one hand, place it on the surface of a flat bench plate or anvil, Fig. 4-76. Strike the metal with firm, even blows, that touch one another. Do not pound the metal so hard that it stretches. Keep the blows firm and evenly spaced, working from one edge to the other. Continue this procedure, working from one end

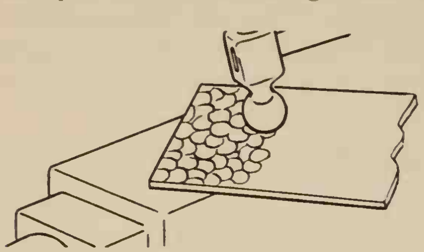


Fig. 4-76. Peening the surface of metal.

of the metal to the other filling in the space to be decorated. The metal will probably tend to bend out of shape as you peen. To straighten the metal, place it on a flat surface and strike it with a wood mallet.

If it is necessary to decorate the other side, place a piece of soft copper on the anvil. Lay the peened side of the metal on the copper, and follow the procedure used in peening the first side. Slightly heavier blows will be necessary to obtain the same texture as that produced on the first side.

SMOOTHING METAL SURFACES WITH ABRASIVES

Metal projects are more attractive when properly finished. An appropriate finish adds to the quality of craftsmanship. To obtain a beautiful, finely polished piece of work is not difficult if a few general rules are kept in mind.

Most metals will take a fine polish if the proper abrasive is used. An abrasive is a material that cuts away other materials that are softer than itself. Abrasives may be selected from coarse grits that are fast cutting, to powders as fine as talcum that can be used for polishing

There are two types of abrasives. Natural abrasives which are found in a natural state and artificial abrasives which are man-made. Emery and corundum are commonly used natural abrasives. Emery is about 60 per cent aluminum oxide and 40 per cent iron oxide. Corundum is about 85 per cent aluminum oxide and 15 per cent iron oxide.

Artificial abrasives are more commonly used on metal. There are two principal artificial abrasives, Silicon Carbide and Aluminum Oxide. Silicon carbide is made by heating coke, sawdust, salt, and pure silica sand to a high temperature, in an electric furnace. Aluminum oxide is made from bauxite ore, similar to that used in refining aluminum. It is also made in an electric furnace.

Abrasive materials which come from the furnace are in chunk form. These chunks are crushed into small particles--grits or grains. The size of an abrasive grain is determined by the size screen they will pass through. For example, if the screen has 46 openings per inch, the grains that just pass through are size 46. Abrasive grains range in size from 4 to 280. Abrasive flours, which are powdery fine, range from 280 to 600.

SELECTING ABRASIVES

There are many types of abrasives which are produced for various kinds of work. The most common type used in the school shop is abrasive cloth. This can be purchased in sheets 9 x 11 in. or in rolls 1/2 inch to 3 in. wide. For most bench metal work the following grain sizes are recommended:

No. 60 - medium coarse
No. 80 - medium
No. 120 - medium fine
No. 180 - fine

After the work has been carefully filed, a good polish can be obtained by rubbing first with No. 60, and then with No. 80 or finer. For a very high polish, use No. 120, and polish with No. 180. Abrasive cloth is used when it is not necessary to remove a quantity of metal.

When using abrasive cloth to do hand polishing follow this procedure:

1. Tear a piece of abrasive cloth from a sheet or roll.
2. Wrap it around a wood block which is long enough to grip comfortably, Fig. 4-77.
3. Apply a few drops of oil to the surface being polished. Rub the abrasive cloth back and forth. Do not allow the piece of metal with abrasive cloth to rock. Keep it flat against the surface being polished. To polish concave surfaces, wrap abrasive cloth around a rod that is smaller than the curvature of the surface. When polishing convex surfaces, use a strip of abrasive cloth and your fingers. Fig. 4-78.

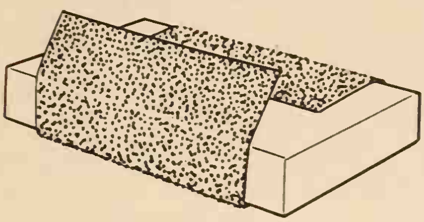


Fig. 4-77. Use abrasive cloth wrapped around a wood block to smooth flat surfaces.

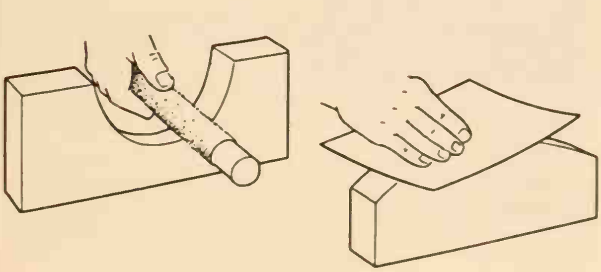


Fig. 4-78. Polishing concave and convex surfaces.

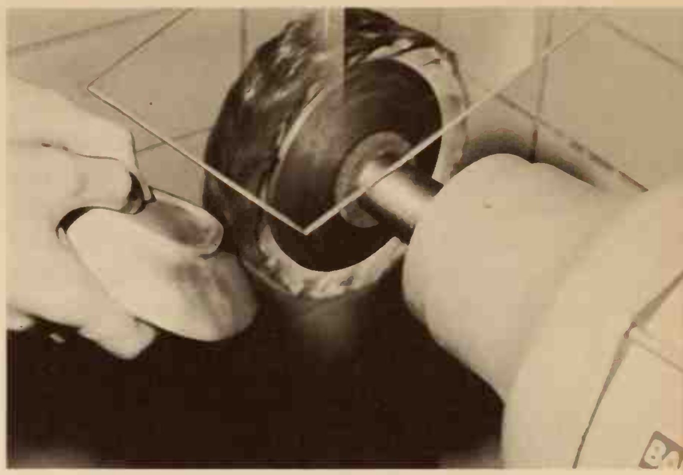


Fig. 4-79. Buffing metal.

BUFFING

Some projects in metalwork require a very highly polished surface. This can be done by using a buffing wheel and a buffing agent, Fig. 4-79. Buffing is not done until all visible tool marks and deep scratches have been removed with abrasive cloth as previously described. There are two basic types of buffing compounds: cutting compounds and burnishing compounds. Tripoli is one of the common cutting compounds that is used as a buffing agent. Tripoli is made from limestone having a high silica content. The silica grains are very soft and porous. For shop use, the powder is mixed with a grease base to form a stick or cake. Red and white rouge are two common burnishing (or coloring) compounds.

SAMMY SAFETY
Says:

"Before using the buffer, remove jewelry from your fingers and wrist. Roll your sleeves above your elbows. Place a face shield or safety glasses over your eyes."

The following procedure is used for buffing metal:

1. Turn the buffer motor on and apply a stick of polishing compound lightly

against the face of wheel. Hold the compound below the center of the wheel so it will tend to pull the compound toward the machine. After the wheel has been loaded with buffing compound add more compound sparingly as needed. Too much compound on the wheel will cause it to stick and build up on the metal being buffed. A different buffing wheel should be used when changing grades of compound. Mark the buffing wheels for the grades of compounds being used so they will not get mixed.

2. Grip the work securely with both hands and press it firmly against the rotating wheel. Be sure to keep the work below the center of the wheel.

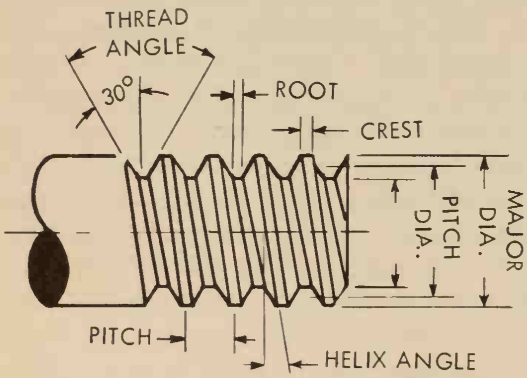


Fig. 4-80. Parts of a thread.

Move the work back and forth across the face of wheel as you buff the surface.

3. After the polishing has been completed, wash the work with soap and hot water. Dry with a soft clean cloth. Be careful not to touch the metal with your hands.
4. To maintain a high luster, coat the work immediately with clear lacquer, plastic, or wax.

CUTTING THREADS

The cutting of threads on metal rods (called external threads) and on the interior of holes drilled in metal (called interior threads) is an important phase of metalwork. The metalworker uses threads to transmit motion, to provide for adjustments, and to fasten parts together.

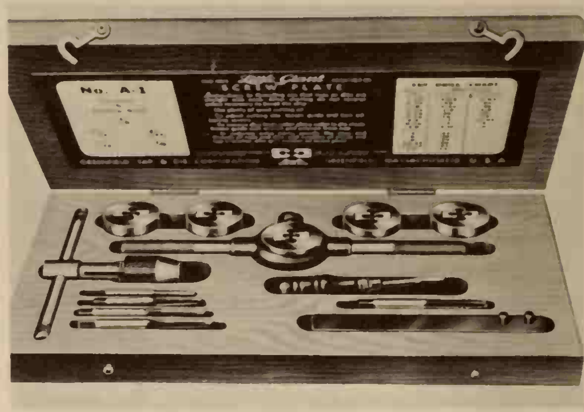


Fig. 4-81. A set of taps and dies. (Greenfield Tap and Die Corp.)

The American National thread system is the most common one used in the United States. The American National is a 60 degree thread with the crest and root flattened. Fig. 4-80. There are two common series. The National Course (NC), which is used for general purpose work, and the National Fine (NF) which is used for precision assemblies such as aircraft engines, automobiles, and adjusting mechanisms.

Taps and dies are the tools used for cutting threads. Taps are used for cutting

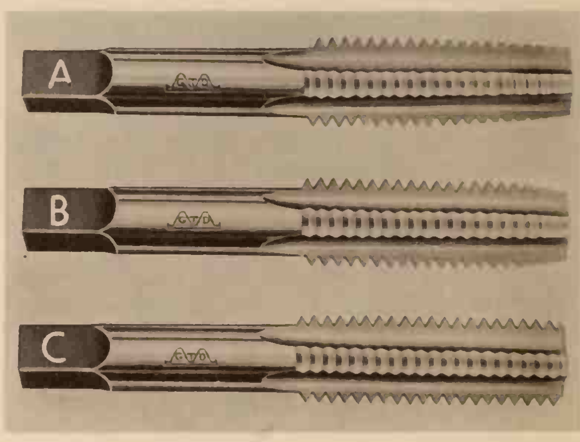


Fig. 4-82. Set of taps. (A) Taper; (B) Plug; (C) Bottoming.

threads on the interior of holes. Dies are used to cut threads on the surface of metal rods. Fig. 4-81 shows a set of taps and dies.

CUTTING INTERNAL THREADS

A tap is a piece of hardened steel which has a threaded portion for cutting threads. The shank of the tap has a square end which is gripped by the tap wrench that is used to turn the tool. Hand taps are usually provided in sets of three taps for each diameter and thread series. Each set contains a taper tap, a plug tap, and a bottoming tap, Fig. 4-82. The taper tap is used to start or cut threads completely through open holes, Fig. 4-83a. To thread a partly open hole, start with a taper tap and finish

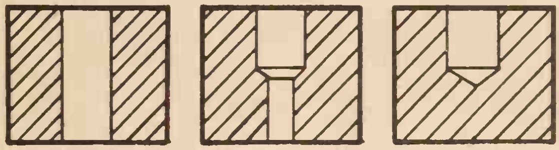


Fig. 4-83. Kinds of holes to be threaded. (A) Open hole; (B) Partly open hole; (C) Closed hole.

the threading with a plug tap, Fig. 4-83b. To cut threads to the bottom of a closed hole, start the threading with the taper tap, then use the plug tap, and finish the threading operation with the bottoming tap, Fig. 4-83c. The tap size is stamped on the shank. For example, in the N.C. and N.F. series, if the tap is stamped 1/4 - 20 N.C., it means that the thread is 1/4 in. in diameter, there are 20 threads per inch and it is National Course. Taps are held in tap wrenches while they are being used. There are two types--the T-handle that is used for small taps, and the adjustable tap wrench that is used for larger sizes, Fig. 4-84.

Following is the procedure for tapping a hole:

1. Select the correct size tap with the desired number of threads per inch.
2. Select the correct size tap drill. Refer to Fig. 4-85. If the exact letter or number drill is not available, use the next larger fractional drill shown in Fig. 4-43.
3. Drill the hole carefully.
4. Secure the tap in the tap wrench. Insert the tap in the hole and start turning the tap in a clockwise direction, Fig. 4-86. Apply enough downward pressure to start the tap cutting.

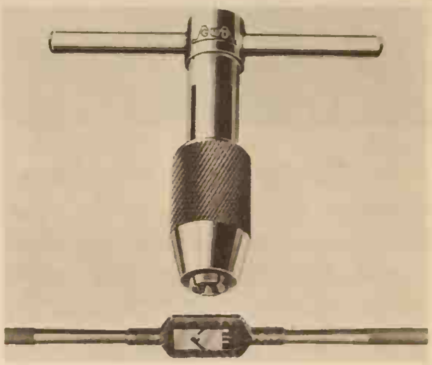


Fig. 4-84. Tap wrenches. Above. T-handle tap wrench. Below. Adjustable tap wrench.

Size of Tap		Size of Tap Drill				Clearance Drill	
National Coarse	National Fine	Number Drills	Letter Drills	Fractional Drills	Decimal Equivalent	Drill Size	Decimal Equivalent
#4-40	.....	43	.....	.....	0.0890	#31	0.1200
	#4-48	42	.....	.....	0.0935	#31	0.120[illegible]
#5-40	.....	38	.....	.....	0.1015	#29	0.1360
	#5-44	37	.....	.....	0.1040	#29	0.136[illegible]
#6-32	.....	36	.....	.....	0.1065	#25	0.1495
	#6-40	33	.....	.....	0.1130	#25	0.1495
#8-32	.....	29	.....	.....	0.1360	#16	0.1770
	#8-36	29	.....	.....	0.1360	#16	0.177[illegible]
#10-24	.....	25	.....	.....	0.1495	13/64	0.2031
	#10-32	21	.....	.....	0.1590	13/64	0.2031
#12-24	.....	16	.....	.....	0.177[illegible]	7/32	.2187
	#12-28	14	.....	.....	0.1820	7/32	0.2187
1/4"-20	.....	7	.....	.....	0.2010	17/64	.265[illegible]
	1/4"-28	3	.....	.....	0.213[illegible]	17/64	.2656
5/16"-18	.....	...	F	.....	.2570	21/64	0.3281
	5/16"-24	...	I	.....	0.272[illegible]	21/64	.3281
3/8"-16	.....	...	.....	5/16	0.3125	25/64	.3[illegible]6
	3/8"-24	...	Q	.....	.3320	25/64	.39[illegible]
7/16"-14	.....	...	U	.....	.3[illegible]8[illegible]	29/64	.4531
	7/16"-2[illegible]	...	.....	25/64	.3[illegible]6	29/64	.4531
1/2"-13	.....	...	.....	27/64	.421[illegible]	[illegible]3/64	.[illegible]15[illegible]
	1/2"-20	...	.....	2[illegible]/64	.4[illegible]31	33/64	.515[illegible]
9/16"-12	.....	...	.....	31/64	.4[illegible]44	37/64	.57[illegible]1
	9/16"-18	...	.....	33/64	.5156	37/64	.5781
5/8"-11	.....	...	.....	17/32	.5312	41/64	.[illegible]4[illegible]
	5/8"-18	...	.....	37/64	.57[illegible]1	41/64	.[illegible]4[illegible]
3/4"-10	.....	...	.....	21/32	.6[illegible]62	4[illegible]/64	.7[illegible]
	3/4"-16	...	.....	11/16	.[illegible]875	4[illegible]/64	.7[illegible]
7/8"-9	.....	...	.....	4[illegible]/64	.7[illegible]5[illegible]	57/64	.[illegible]
	7/8"-14	...	.....	13/16	.[illegible]12[illegible]	57/64	.8[illegible]
1"-8	.....	...	.....	7/8	0.8750	1 1/64	1.[illegible]15[illegible]
	1"-14	...	.....	15/1[illegible]	[illegible].[illegible]375	1 1/64	[illegible]

Fig. 4-85. Tap drill sizes.

Fig. 4-86. Cutting internal threads.

5. Check the tap to see if it is starting square with the hole. Remove tap wrench and check work with a square, Fig. 4-87. If the alignment of the tap is out of square, correct the error by applying sidewise pressure as you continue turning the tap.
6. If the hole is being tapped in steel apply a lubricant. Lard oil can be used. Cast iron is tapped dry.
7. Turn the tap forward about one-half

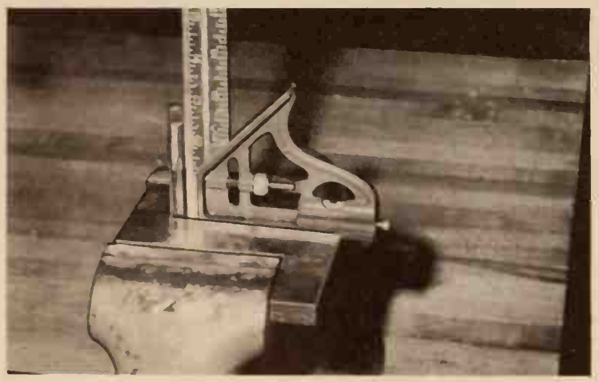


Fig. 4-87. Checking a tap after it is started to make sure it is square with the piece.

turn, then back it up until you feel the chips break loose. Repeat this procedure until threading has been completed. When tapping cast iron the tap should not be backed but you should continue forward until threading is completed. CAUTION: Be careful not to force tap if it gets stuck. Taps are very brittle and will break easily. Gently move the tap back and forth until it loosens.
8. Remove the tap by backing it out carefully. If it gets stuck, work it back and forth gently to loosen.

When cuting threads in a partly open or closed hole, be very careful as the tap comes close to the bottom of the hole. Remove the tap and clean out the chips often, so the tap can reach the bottom of the hole.

CUTTING EXTERNAL THREADS

External threads are cut by hand with a die held in a die stock, Fig. 4-88. The die cuts threads on the external surface of

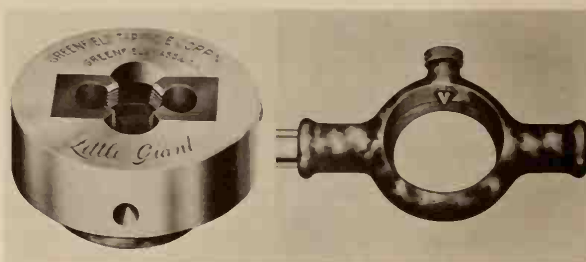


Fig. 4-88. Left. Die. Right. Die stock. (Greenfield Tap and Die Corp.)

rods and bolts that will fit into standard-size nuts, tapped holes, or fittings. Some dies are adjustable while others are solid dies which are not adjustable, Fig. 4-89.

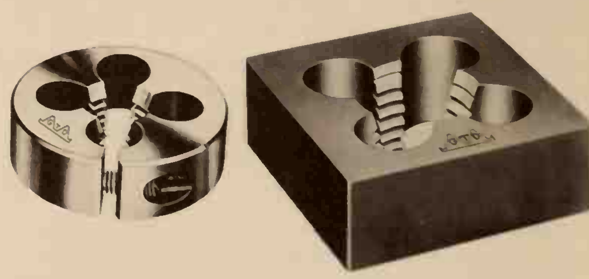


Fig. 4-89. Left. Adjustable die. Right. Solid die.

Following is the procedure for cutting external threads:

1. Chamfer the end of the stock, Fig. 4-90. The chamfer can be cut with a file or on a grinder.

2. Select the correct size die for the diameter of the rod to be threaded. An N.C. or N.F. die can be used. When the number of threads per inch is not known, use a screw pitch gauge, Fig. 4-91. This gauge contains several thin blades which have saw like teeth on them. To use the gauge, try blades until one is found that fits the threads to be duplicated. The number of threads per inch is stamped on the blades.

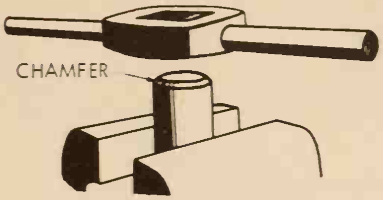


Fig. 4-90. The die will start more easily if the end is chamfered.

3. Place the die in the die stock. Tighten the setscrews in the die stock, so the die is held firmly in place. If the die is adjustable, set it to cut oversize threads first. You can always make the threads smaller but you cannot make them larger. A tap is not adjustable, so it is better to tap first, then cut the external threads to fit the tapped hole.

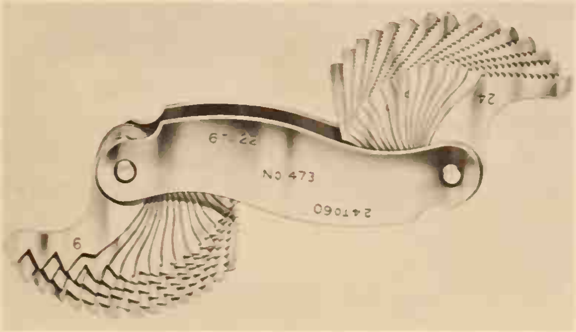


Fig. 4-91. A screw pitch gauge. (L. S. Starrett Co.)

4. Fasten the work firmly in a vise in a vertical or horizontal position.
5. Place the die over the end of work. Die threads are tapered. Be sure the tapered side starts the cut. Reverse the die only when it is necessary to cut full threads up to a square shoulder.
6. Start cutting the threads by turning the die stock clockwise and applying downward pressure. Be careful to start the threads straight and keep them straight. Add a little cutting oil when threading steel. Back up the die occasionally to break the chips loose. Continue until threading is completed.
7. Check the threaded work to see if it fits the tapped hole or nut. If the threads are too tight, adjust the die to take a little deeper cut and run the die over the threaded section again.

METAL FASTENING DEVICES

Fastening devices are used to hold pieces of a project together. The type, shape, and size of fastening devices to be used depend upon the nature of the work. For example, rivets are used to hold pieces together permanently. Bolts or screws are used when the pieces may be disassembled occasionally or have to be adjusted.

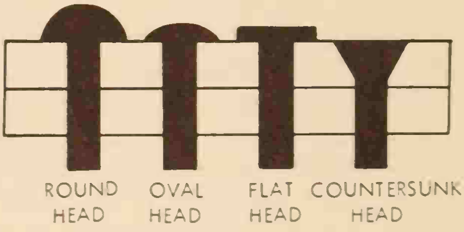


Fig. 4-92. Common rivet shapes.

RIVETING

Rivets can be used for ornamentation as well as fastening pieces of metal together. Soft iron rivets are used for wrought iron projects. They are available in round, oval, flat, and countersunk heads, Fig. 4-92. The

most common size rivets used are 1/8 and 3/16 in. in diameter and 1 in. long. Projects made of aluminum, copper, or brass may be fastened together with rivets made of the same material, or contrasting metal. The most common size non-ferrous rivets are 1/16 and 1/8 in. in diameter with round heads. The procedure for riveting is as follows:

1. Select the correct size and shape rivets. Use a flat-head rivet if it is not to be noticeable. Round-head rivets are used if they are to be part of the design. The rivets must be long enough to go through both pieces of metal and extend beyond by one and one-half times the diameter if the head is to be rounded on both sides. If the rivet is to be flush, allow just enough material to stick through to fill the countersunk hole.

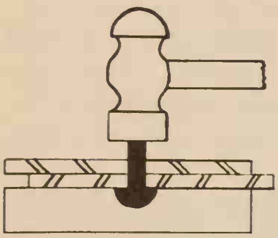


Fig. 4-93. Use a riveting plate or riveting set to protect the head of the rivet.

2. Locate and drill the holes. Countersink the hole if the rivet is to be flush with the surface. If several rivets are to be used, drill only one hole and finish the riveting process before drilling the other holes. This procedure makes it easier to line up the remaining holes when joining two pieces.
3. Insert the rivet in the hole, and place the head against a solid piece of material. The heads of countersunk rivets should be set on an anvil or block of iron, and round-head rivets should rest in a cup-shaped hole so the shape of the head will not be damaged, Fig. 4-93. To rivet scroll work, place the piece to be riveted over a steel rod fastened in a vise or to a bench, Fig. 4-94.
4. Upset the rivet by striking the end with the flat face of the ball-peen hammer, Fig. 4-95. This causes the rivet to expand and fill up the hole. If the rivet is to be formed, shape the flattened end of rivet by striking it with the peen end of the hammer. If the back of the rivet is to be flat, strike it with the peen end of the hammer to fill countersunk hole. Then finish operation by striking with the flat face of the hammer.

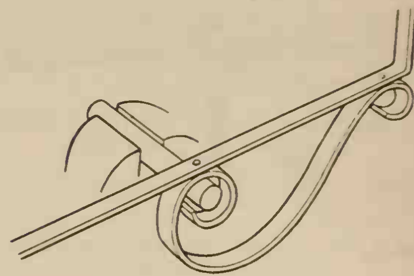


Fig. 4-94. A rod fastened in a vise can be used to rivet scroll work.

MACHINE SCREWS

Machine screws are used in tapped holes for the assembly of metal parts. Sometimes machine screws are used with nuts. Most machine screws are made of steel or brass. They can be purchased in

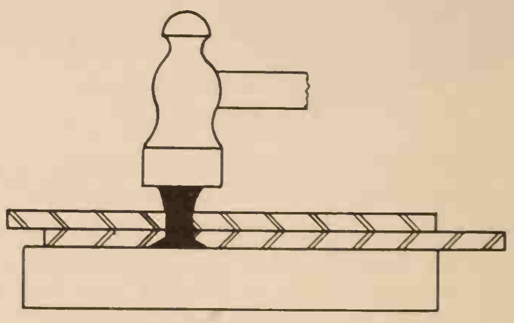


Fig. 4-95. Upsetting a rivet.

a variety of diameters, lengths, and head shapes. Here is a typical example of how to give the specifications for a machine screw: 1 inch (length), 6-32 (thread-diameter), round head (head shape), steel (material). 6-32 means that the screw gage is No. 6, and that it has 32 threads per inch. Most of the time you will use the

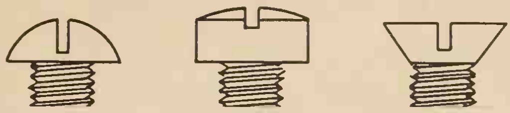


Fig. 4-96. Common types of machine screws.

common types of machine screws shown in Fig. 4-96. Square or hex nuts can be used on machine screws. The head of a machine screw may be specified either slotted, for use with a plain screwdriver, or with a Phillips head for use with a special Phillips screwdriver.

STOVE BOLTS

Stove bolts were developed for use on stoves as the name suggests. They are used for many other jobs where accuracy and strength are not required. Stove bolts have coarse threads that make a loose fit

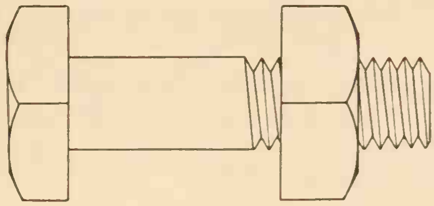


Fig. 4-97. Machine bolt.

with the threads of the square nut. Stove bolts can be purchased with flat heads, round heads, or oval heads.

MACHINE BOLTS

Machine bolts are made with square or hexagonal heads, and the nuts may also be of either type, Fig. 4-97. They may be purchased in a variety of diameters, lengths, and standard N.C. or N.F. threads. They can be furnished in three grades--rough, semi-finished, or machine-finished.

NUTS

Square and hexagonal nuts are standard, but there are also many special nuts available, Fig. 4-98. One of these is the wing nut which is used where frequent adjustment is necessary. Cap, or acorn nuts are used when appearance is im-

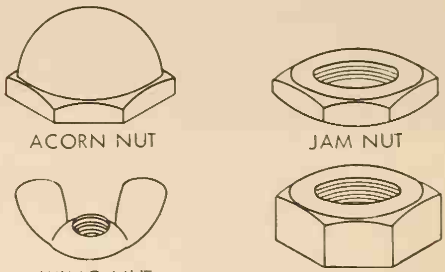


Fig. 4-98. Nuts.

portant. A jam nut is used on top of a standard hexagonal nut to lock it in position.

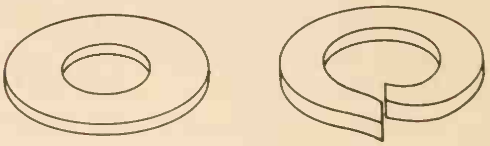
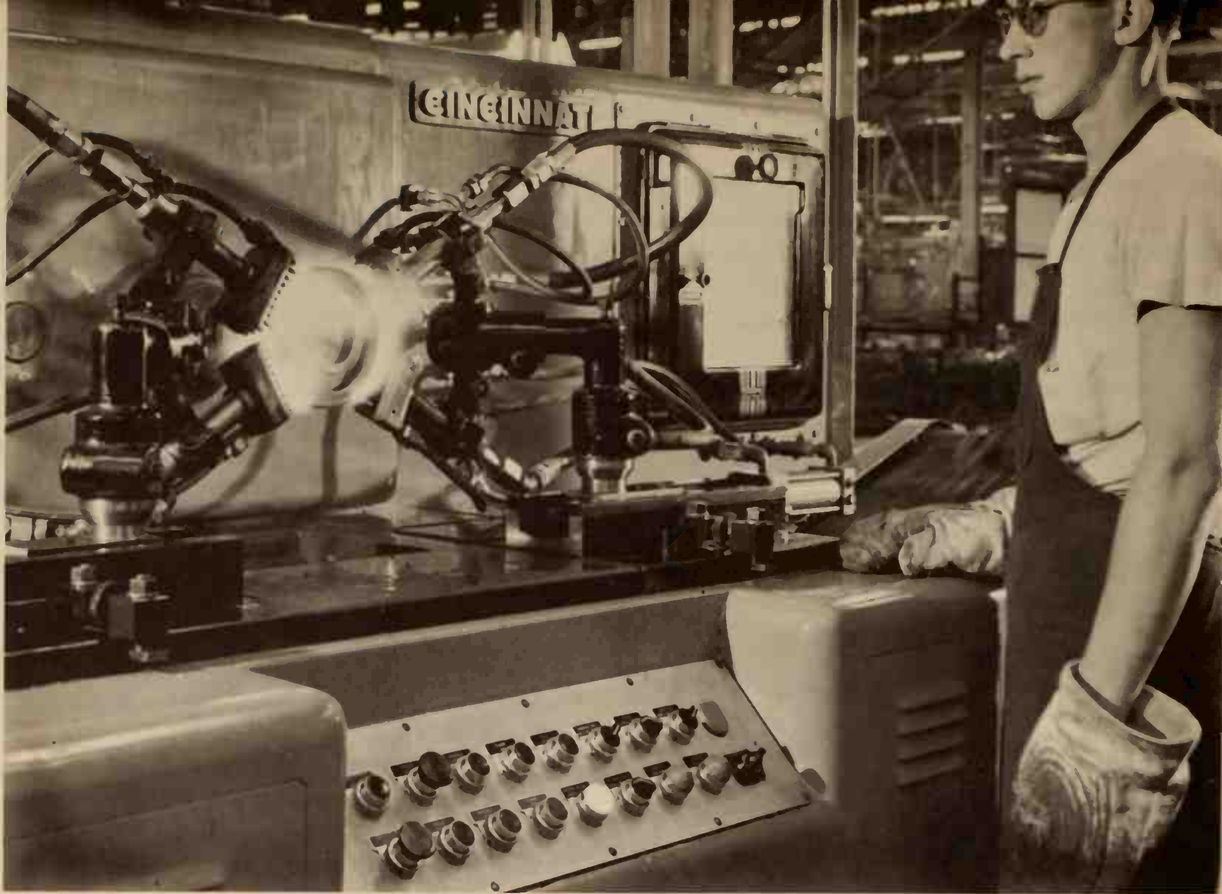


Fig. 4-99. Two common types of washers.

WASHERS

There are two common types of washers, the flat and the split lock, Fig. 4-99. Flat washers serve the function of providing larger bearing surfaces and preventing damage to the surfaces of the metal parts through which a bolt passes.



Flame throwing principles being used to harden gear of engine camshaft sprocket at Ford Motor engine plant in Lima, Ohio. Part is ejected into an oil bath where it is quickly quenched.

Split lock washers are used under nuts to prevent them from loosening by vibration.

QUIZ - UNIT 4

1. Why is bench metal basic to all other areas of metal work?
2. List four things a combination square can be used for in metal work.
3. How can the surface of a piece of metal be prepared so scribed lines may be seen more clearly?
4. How many hacksaw teeth should be in contact with the metal when cutting?
5. What is a cold chisel used for?
6. Which method of filing should be used to obtain a smooth surface?
7. Name three systems used to designate the size of drills.
8. When drilling holes larger than 3/8 in. it is good practice to drill a --- first.
9. If you are using 1/8 in. thick band iron and you are going to make two right angle bends, how much should be added to the length of the stock?
10. If a piece of pipe requires a sharp bend it should be filled with --- or ---.
11. What is the difference between natural and artificial abrasives?
12. Which abrasive is the finest, No. 80 or No. 120?
13. Tripoli is a cutting compound that is used as a --- ---.
14. The American National thread is a --- degree thread.
15. Internal threads can be cut by hand with a hand ---.
16. What is the difference between the tap drill size and the clearance drill size?
17. External threads can be cut by hand with a ---.
18. List four metal-fastening devices.

SHEET METAL

UNIT 5

1. The sheet metal industry.
2. How to use sheet metal tools and machines.
3. How to fabricate sheet metal projects.

THE FIELD OF SHEET METAL WORK

The sheet metal field and its related areas of work employ several million metalworkers. This area of metalwork is concerned mostly with the building trades. It includes the installation of heating and air conditioning systems, roof work, and metal trim. Sheet metal work is also required in the manufacturing of automobiles, rockets, railroad cars, ships, airplanes, metal furniture, and household appliances. People employed in the sheet metal trades work mostly with sheet steel (black and galvanized), tin plate, copper, brass, and aluminum. They use sheets of metal ranging from a few thousandths to 1 in. or more in thickness. The sheet metal industry and the craftsmen who work in it have contributed much to make life more comfortable and enjoyable.

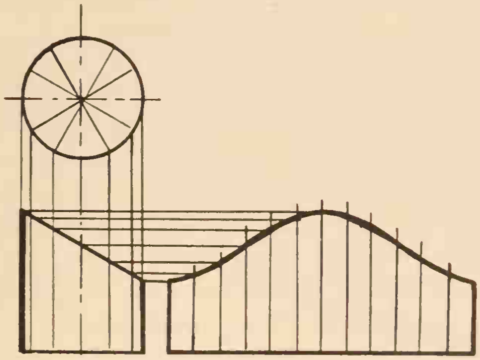


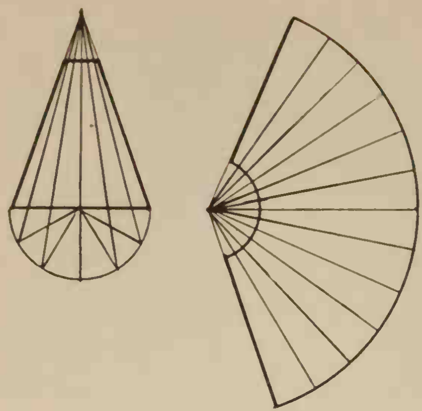
Fig. 5-1. Parallel-line development. This kind of pattern development may be used to lay out a scoop.

In this area of metalwork you will learn to cut, form, shape, and assemble sheet metal stock. You will make such items as boxes, pans, funnels, mailboxes, and cannister sets. Most craftsmen find sheet metal work very interesting. It is also a fascinating hobby. Some of the fundamentals you studied in Unit 4, will be used in this Unit.

LAYING OUT AND DEVELOPING PATTERNS

Before constructing a sheet metal project it is necessary to first develop a stretchout (pattern) either on a sheet of paper, or on the metal. The inexperienced sheet metal worker should draw the pattern on paper first so it can be checked to see if any mistakes have been made. The pattern is then transferred to the metal by scribing the lines directly to the metal. Use a pencil if a scriber mark is objectionable. If several pieces of the same kind are to be made and especially where irregular curves are involved, a metal template is used. This template is placed on the metal and a scriber is used to trace around the outside.

Many sheet metal articles require developments. There are three kinds of pattern development--Parallel-line development, Fig. 5-1, Radial-line development, Fig. 5-2, and a combination of Parallel-line and Radial-line development, Fig. 5-3. The latter of these includes triangles as well as cones and cylinders, and is sometimes referred to as triangulation. Refer to Unit 10, in the Build-A-Course Series



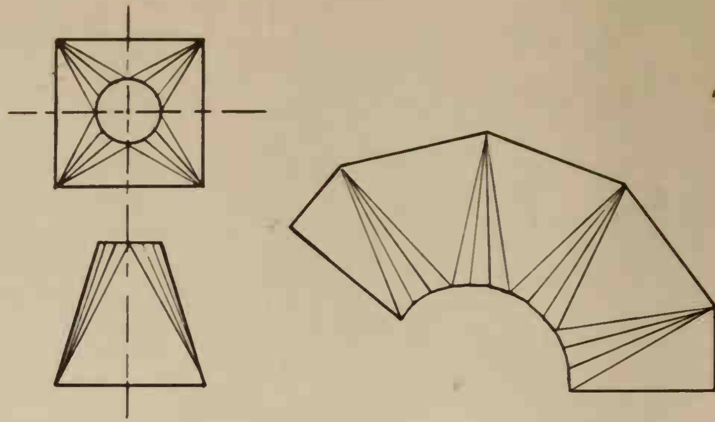


Fig. 5-2. Left, Radial-line development that might be used for a funnel. Fig. 5-3. Right, A combination of parallel-line and radial-line development. This kind of pattern development is used when it is necessary to go from square to round, as in heating and ventilating duct work.

on Drafting which explains how to develop sheet metal patterns.

CUTTING SHEET METAL

Sheet metal which is 18-ga. or less in thickness, can be cut with bench shears. The standard tinner's snips will cut metal 22-ga. or lighter. Some of the more common snips are: Straight snips which are for cutting straight lines and to cut on the outside of large curves, Fig. 5-4; Hawk-billed snips which have narrow, curved blades and are used for making curved cuts; Aviation snips which are very useful for making various types of cuts, Fig. 5-5. Aviation snips are very handy for cutting compound curves and intricate designs. They are made in three styles--the right, which cuts to the right; the left, which cuts to the left; and the universal, which cuts either right or left.

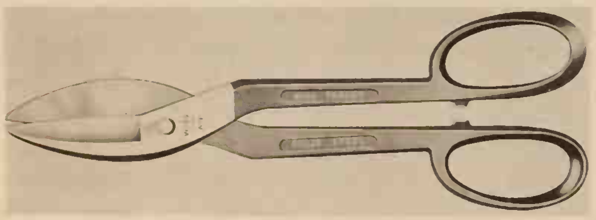


Fig. 5-4. Straight snips. (J. Wiss & Sons Co.)

When cutting with snips, never cut with the full length of the blades. If the blades of the snips are completely closed, the points will tear the metal sidewise where they meet. Stop each cut approximately 1/4 in. from the end of the blades, and start the new cut with the throat. The throat is that part of the blades nearest to the pivot pin. Always cut to the right of the layout line when possible. When cutting outside curves, first rough cut to within about 1/8 in. of the layout line with aviation snips. Then finish the work by carefully cutting around layout line, Fig. 5-6. To cut inside curves, first punch or drill a hole in the waste stock large enough to allow the blades of the hawk-bill snips to get started. Insert the snips from the underside of stock and rough cut the inside opening to within about 1/4 in. of the layout line. Then trim the hole to size, Fig. 5-7.

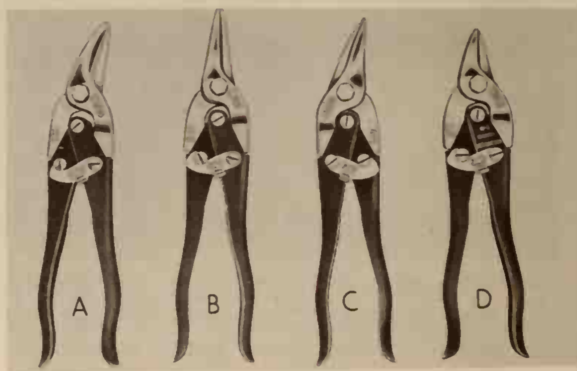


Fig. 5-5. Aviation snips. (A) cuts to the left; (B) cuts to the right; (C) cuts straight or curved; (D) is used for notching.

When the snip blades become dull, they can be sharpened by grinding. Take the two

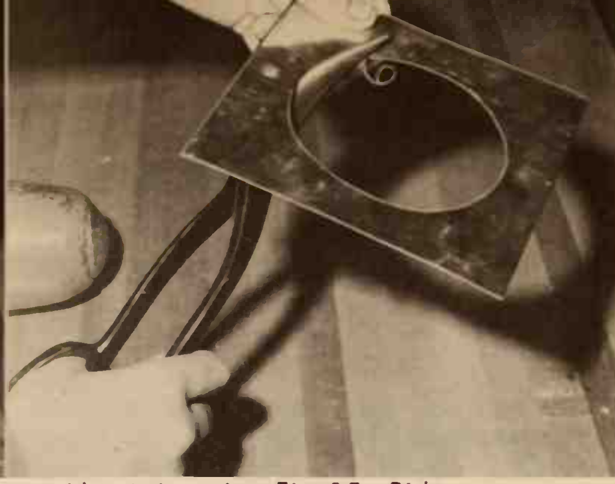


Fig. 5-6. Left, Cutting on outside curve with aviation snips. Fig. 5-7. Right, Cutting on inside opening with hawk-bill snips.

blades apart and grind them to an included angle of 85 deg. Put the blades together again and adjust the blade tension by turning the nut on the pivot bolt or pin. The blades should be just tight enough to remain in any position in which you open them. Keep the pivot well oiled. Keep the blades closed when the snips are not being used. Remember snips are strictly sheet metal tools and should not be used to cut wires, bolts, rivets, or nails.

Electric portable shears are very handy for cutting sheet metal which is 18 ga. or lighter, Fig. 5-8. This machine can be used to make both straight and curved cuts. It will cut a minimum radius of about 1 in. To use the shears, place the metal between the cutters. Turn on the switch and guide the cutters along the line to be cut.

Some shops are equipped with squaring shears, Fig. 5-9. This machine can be used to trim and square sheet metal 18 ga. or lighter. The size of the machine is determined by the width of material it will cut. The common sizes are 30 or 36 in. To use the machine set the back gauge at the rear of the shears, to cut material to the desired length. Insert the material from the front and hold it firmly against the side and rear gauges. Press the treadle down with your foot to make the cut. When the work is inserted from the back use the front gauge to control the length of cut. The side gauge which is

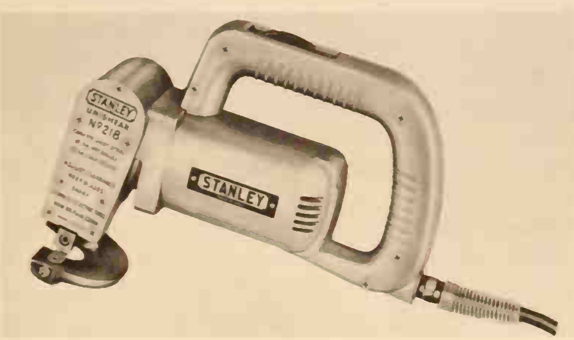
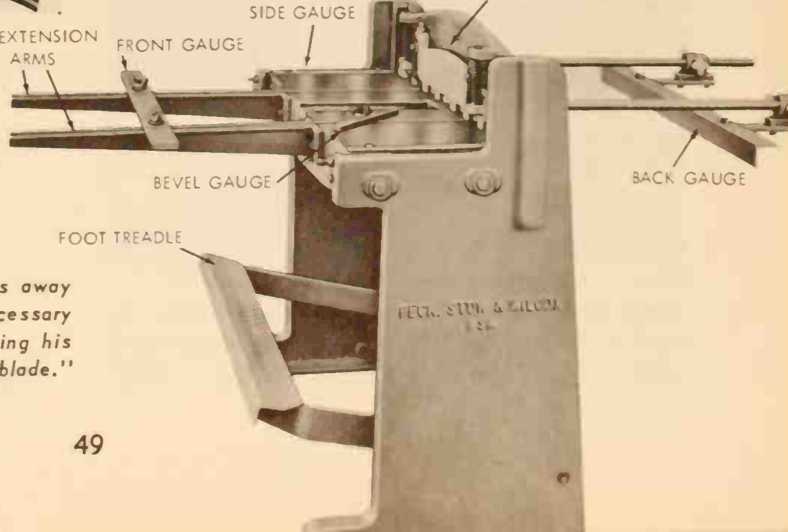


Fig. 5-8. Electric portable shears.

SAMMY SAFETY
Says:

"When using Squaring Shears, keep your fingers away from the cutting blade at all times. When it is necessary to have a helper, warn him of the danger of getting his foot under the treadle or his hands near the cutting blade."

Fig. 5-9. Squaring shears. (Peck, Stow & Wilcox Co.)



adjustable should be kept at right angles to the cutting blade.

BENDING SHEET METAL

Sheet metal can be bent by hand or with a machine. A craftsman should know how to bend sheet metal by hand because machinery is not always available. Also, there are occasions where a machine in the shop does not have the necessary capacity to perform the operation.

BENDING BY HAND

To make angular bends by hand, clamp two pieces of hardwood or angle iron in a vise, with the sheet metal between them. If the metal is too large to fit in the vise, use two C clamps, Fig. 5-10. The line

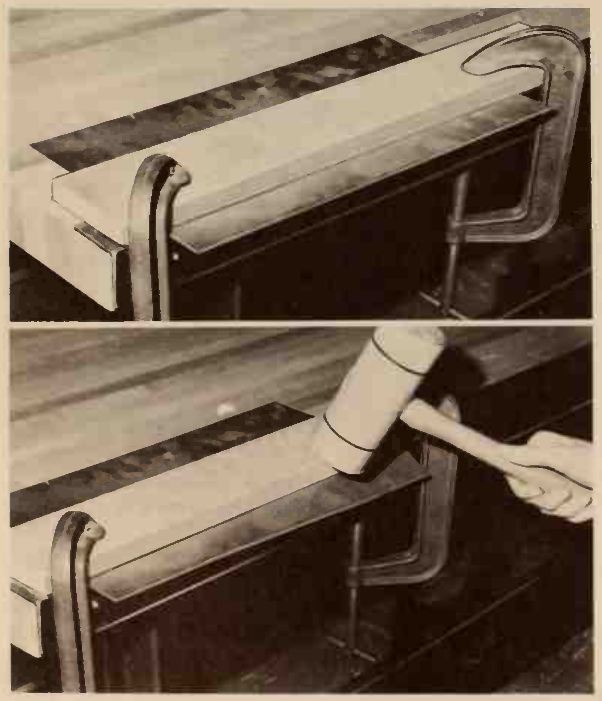


Fig. 5-10. Above. Metal clamped to bench for bending. Below. Bend the metal gradually working back and forth across the metal.

where the metal is to be bent, should be even with the upper edge of the jig. To bend the metal down, start by striking light blows with a mallet at one end and work along the full length of the stock. Continue working back and forth making a gradual bend.

There are several sheet metal stakes which can be used for many bending and forming operations, Fig. 5-11. A hatchet stake can be used to make a sharp angle bend. To bend metal this way, place the bend line of the piece over the sharp edge

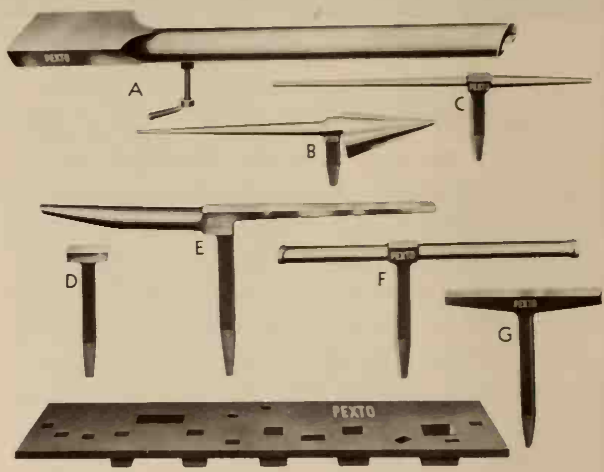


Fig. 5-11. Sheet metal stakes: (A) hollow mandrel; (B) blowhorn; (C) candle mould; (D) common square; (E) beakhorn; (F) double seaming; (G) hatchet; (H) stake plate. (Peck, Stow & Wilcox Co.)

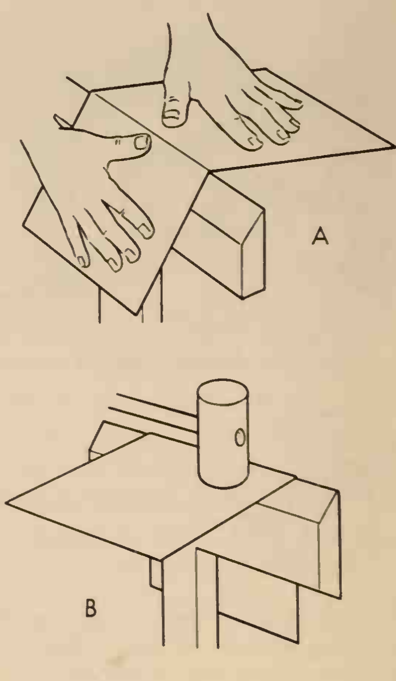


Fig. 5-12. Making a sharp bend over a hatchet stake.

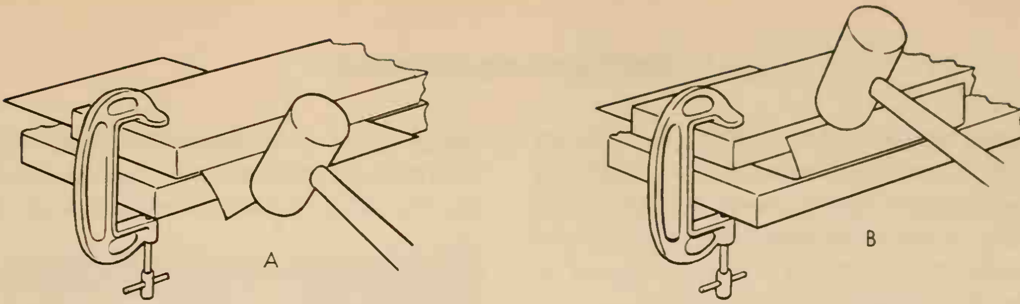


Fig. 5-13. Bending a hem between two boards.

of the stake. Then press the metal down with your hands, Fig. 5-12a. Square up bend with a wood mallet, Fig. 5-12b.

To bend a box by hand, first clamp the metal as shown in Fig. 5-13a. Bend the hem at a right angle. Release the clamps and remove the metal. Clamp the metal on the edge of a bench with the partially turned hem up, Fig. 5-13b. Close the hem with a mallet and a block of wood Fig. 5-14. A

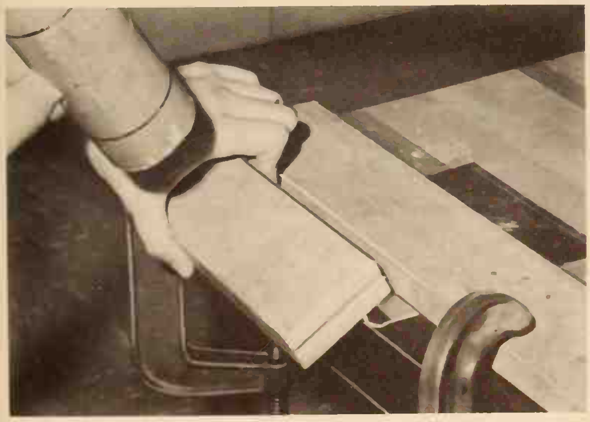


Fig. 5-14. Closing a hem with a mallet and block of wood.

short hem can be made with a hand seamer, Fig. 5-15. First, adjust the hand seamer for the size hem to be bent by setting the knurled screws at the proper distance and clamp them in place with the locking nut. Press the piece against the top surface of a bench with one hand and grip the metal with the hand seamer.

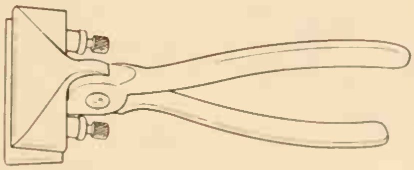


Fig. 5-15. A hand seamer.

Squeeze the handles of the hand seamer so the jaws will not slip off the metal. Bend the hem as far as the seamer will allow it to go. Open the seamer and squeeze the metal to close the hem.

After the hems have been bent by one of the described methods, bend the two ends of the box by using clamps and two pieces of wood. Next, cut a block of wood the exact size of the bottom of the box. Clamp this block in position as shown in Fig. 5-16.

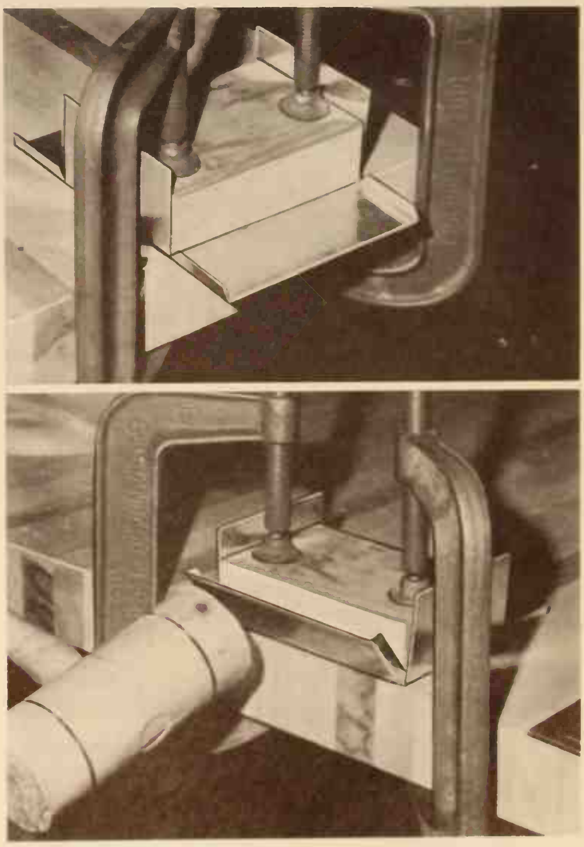


Fig. 5-16. Bending up the sides of a box by hand. Above. Metal clamped in position for bending. Below. Drawing the metal tightly against the block of wood with a mallet.

Then bend up the sides of the box. Draw the metal tightly against the wood block by striking it light blows near the bend with a mallet. Work back and forth across the full length of the bend. Be careful not to dent the metal with the edge of the mallet head.

BENDING CYLINDRICAL FORMS BY HAND

A cylindrical piece may be formed to shape by bending it around a stake, rod, or pipe which is slightly smaller or equal to the diameter to be bent. Light-weight metal can be formed around the stake by hand, Fig. 5-17. To form heavier weights, hold

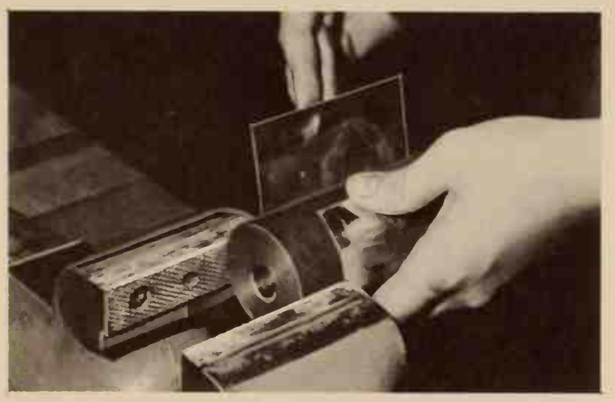


Fig. 5-17. Forming light weight metal around a rod by hand.

the metal on top of a stake with one hand, then strike it glancing blows with a mallet as you feed the piece across the stake, Fig. 5-18. Continue this procedure until the metal has been formed to the desired shape.

FORMING CONE - SHAPED ARTICLES

Cone-shaped pieces such as funnels and spouts should be formed on a tapered stake. A funnel, for example, can be formed over the apron of a blowhorn stake, Fig. 5-19. When the gauge of the metal is too heavy to form by hand use a mallet.

BENDING METAL ON A BAR FOLDER

The bar folder is a folding machine which comes in various sizes, the most common of which has a folding length of 30 in. Fig. 5-20. These machines will

Fig. 5-18. Forming heavier weight metal around a rod with a mallet.

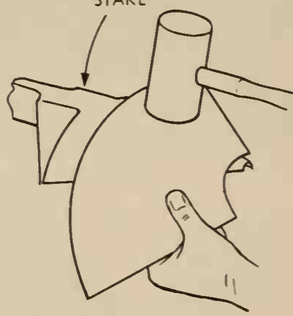


Fig. 5-19. Forming metal over a blowhorn stake.

fold an edge as narrow as 1/8 to 1 in. on metal as heavy as 24 gauge. A 3/16 in. fold is the narrowest bend practicable when using 22 ga. metal.

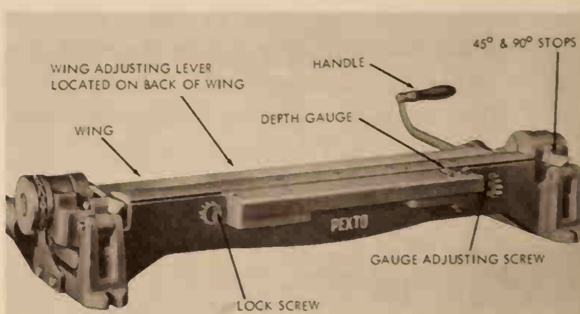


Fig. 5-20. A bar folder. (Peck, Stow & Wilcox Co.)

The bar folder is used for making single or double hems, a sharp or open lock, turning an edge to receive a wire, and turning flanges, Fig. 5-21. To perform these operations there are two adjustments

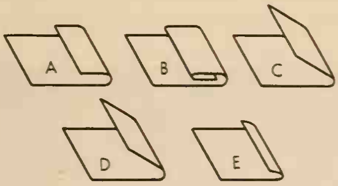


Fig. 5-21. Common hems that can be turned on the bar folder: (A) single hem; (B) double hem; (C) sharp lock; (D) open lock; (E) turned edge to receive a wire.

to make. The depth of the fold which is controlled by turning the gauge-adjusting screw knob in or out, and the sharpness of the fold which is obtained by adjusting the wing. There are two angle stops at the left end of the bar folder. By setting the appropriate angle stop in place the fold may be stopped at 45 or 90 deg. The fold can be stopped at any desired angle from 10 to 120 deg. by setting the adjustable stop at the handle end of the machine.

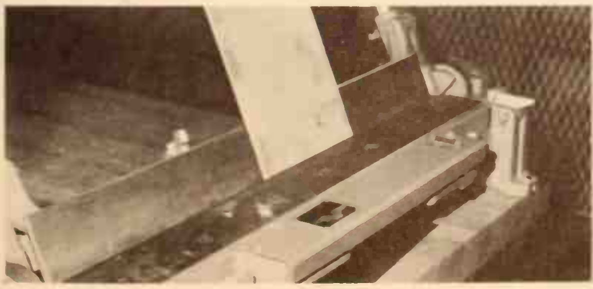
In preparing to use the bar folder, check the edge of the metal to be folded to be sure it is straight, then follow this procedure:

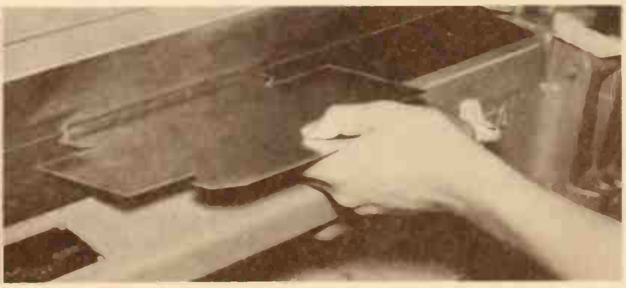
1. Loosen the locking screw, then turn the gauge-adjusting screw until the machine is set to make a fold of the desired width. Tighten the locking screw to hold this adjustment.
2. Loosen the wedge screw on the folding bar and position the wing with the wing-adjusting lever to make an open or closed lock as desired. Tighten the wedge screw to hold this adjustment. When making an open lock for wired edges, set the wing adjusting lever so the distance between the wing and the edge of the folding blade is equal to the diameter of the wire plus about 1/32 in. Set the gauge to make a fold equal to one and one-half times the wire diameter.
3. Place the edge of the metal in the folder and hold it against the gauge tightly. Then pull the handle toward you until the fold is completed, Fig. 5-22. Do not release your grip on the handle until it is in its original position.
4. Return the handle to starting position. Remove the folded metal.
5. If a hem is being made, place the metal on the beveled part of the blade with the fold upward, and set tightly against the wing of the folder, Fig. 5-23. Pull the handle to flatten the fold. Return the handle to its original position, and remove the metal.

BENDING METAL ON A BOX AND PAN BRAKE

The Box and Pan Brake is an ideal machine for bending metal boxes and pans of a size within its limits, Fig. 5-24. Most box and pan brakes found in school shops will bend metal up to 24 in. long, and 16 ga. in thickness. The upper jaw is made up of removable fingers which are of various widths. To bend a box on this machine, fold the hems first. Then fold the two sides at 90 deg. To bend the two ends,

Fig. 5-22. Left, Folding metal in the bar folder. Fig. 5-23. Right, Closing a hem on the bar folder.





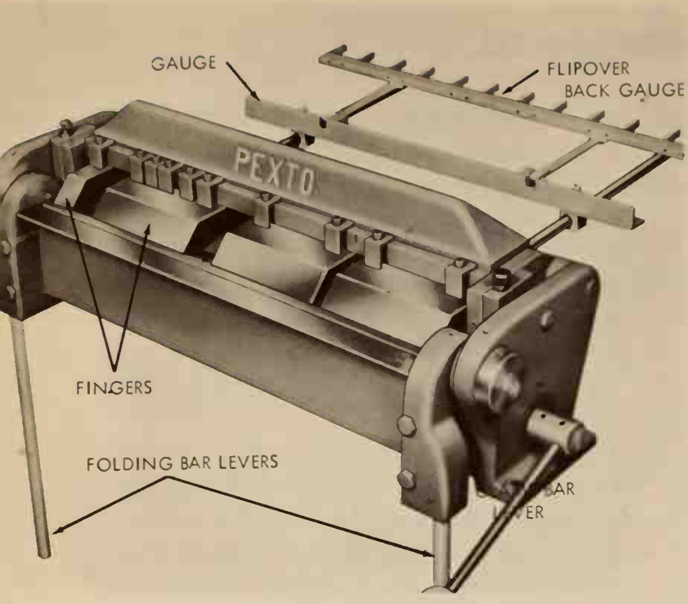


Fig. 5-24. A box and pan brake.

set up the machine with just enough fingers to equal the width of the box. Bend the two ends. Many shapes can be bent on a Box and Pan Brake.

FORMING METAL ON A FORMING MACHINE

The forming machine, or rolls, as they are more commonly called, are used for curving sheet metal and forming cylinders

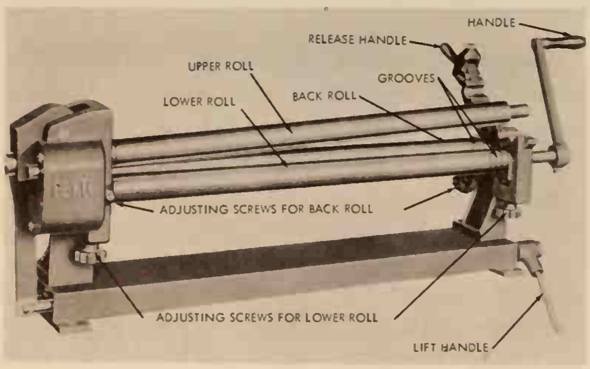


Fig. 5-25. Forming rolls. (Peck, Stow & Wilcox Co.)

of various diameters. The most common forming machines have rolls that are 30 to 36 in. wide and 2 in. in diameter, Fig. 5-25. They can form mild steel sheet metal as heavy as 22 ga. This machine has three rolls. The two front rolls grip the sheet of metal and force it against the rear roll, which bends it upward curving the sheet and forming the cylinder. The lower front roll can be adjusted for different thicknesses of metal. The back roll can be raised or lowered to form different diameter cylinders. The back roll can also be set at an angular, vertical position for

Fig. 5-26. Back roll beginning to form a cylinder.

forming tapered cylinders. To form a cylinder follow this procedure:

1. Adjust the lower front roller up or down so there is just enough clearance between the two front rolls for the sheet metal to slip in under slight pressure.
2. The back roll is then adjusted to a position which will form the cylinder. There is no set rule that may be applied for setting the rear roll. Some metals have more spring than others. Therefore, the adjustment of the rear roll can best be obtained by experimenting. The back roll must be parallel to the front rolls.
3. Insert the sheet metal from the front of the machine between the two front gripping rolls. Turn the hand crank and feed the metal through the front rolls and against upper side of the rear forming roll which bends the metal upward forming the cylinder, Fig. 5-26.
4. Continue turning the hand crank to shape the cylinder. Readjust the back roll if the cylinder is not the correct radius. Lowering the rear forming roll will increase the diameter of the cylinder, and raising the rear form-

ing roll will decrease the diameter of the cylinder.

5. Remove the formed cylinder from the rolls, Fig. 5-27.

To form cone-shaped pieces on the forming machine, adjust the front rolls as before. Set the rear roll at an angle that is

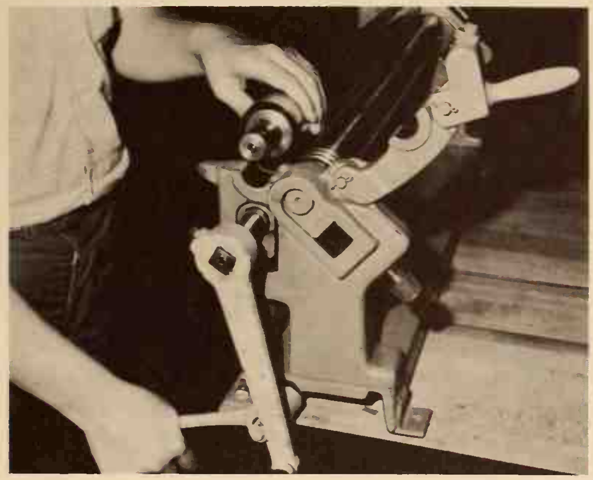


Fig. 5-27. Removing a cylinder from the forming rolls.

approximately the same as the taper of the cone, with the left end of the roll nearer the front rolls. Insert the metal with the long side to the right. Hold the short side of the metal so it will go through the rolls more slowly than the long side as the cone is formed.

The grooves of varying sizes in the right end of the lower and rear rolls are for forming cylinders which have a wired edge, Fig. 5-28. The procedure for forming

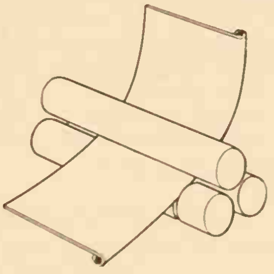


Fig. 5-28. Forming a piece of metal in the rolls with a wired edge.

wired edge metal is the same as described before, except when forming wired material heavier or lighter than 20 ga. When forming wired material heavier than 20 ga. the rear roll of the forming machine must be set at a distance that is slightly greater at the wired end than at the opposite end. Wired material lighter than 20 ga. requires an adjustment that provides a distance between the rear roll and both the upper and lower rolls that is greater at the wired end than at the opposite end.

SHEET METAL SEAMS

A great many methods are employed to strengthen and join pieces of sheet metal. Some of the common seams are shown in Fig. 5-29. Lap seams are generally used in the construction of rectangular objects and small diameter cylinders. Lap seams are usually riveted or soldered. Folded seams are generally used when laying flat seam metal roofing. A folded seam is made by

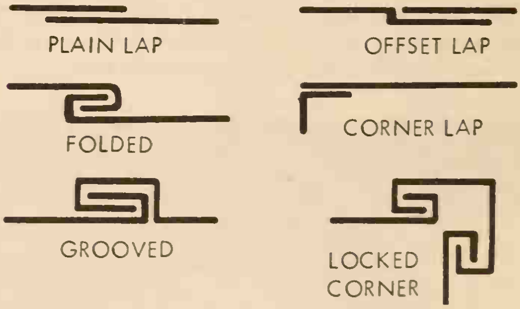
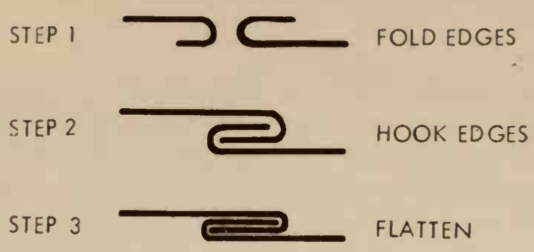


Fig. 5-29. Some of the common sheet metal seams.

turning single edges on the two pieces of the sheet metal that are to be joined, Fig. 5-30. Allow extra material equal to three times the seam width. Hook the two edges together and place the metal over a stake if the work is circular, or on a solid flat surface if the piece is flat. Hammer the seam flat with a wood mallet. Grooved seams are generally used in joining flat pieces of metal, making vertical side seams, in flaring or cylindrically shaped objects, and making longitudinal seams in square or round sheet metal pipes, Fig.



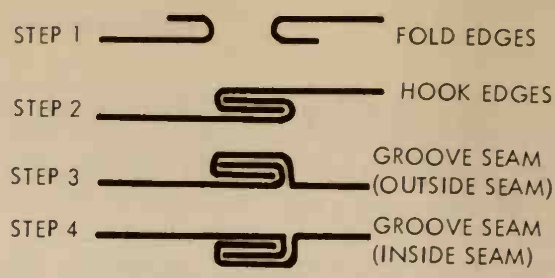


Fig. 5-30. Left, Steps in making a folded seam. Fig. 5-31. Right, Steps in making a grooved seam.

5-31. To make a grooved seam, follow the procedure given for making a folded seam, up to the steps given for closing the seam. To close the seam, select a hand groover of the required size, Fig. 5-32. Always use a hand groover approximately 1/16 in. wider than the finished seam. Place the piece on a suitable support. Set the groover exactly over one end of the seam. Strike the groover a firm blow to close the seam, Fig. 5-33. Continue working back and forth across the seam striking the groover moderate blows with a metal hammer to complete the seam. Fig. 5-34.

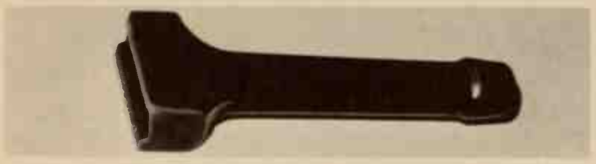
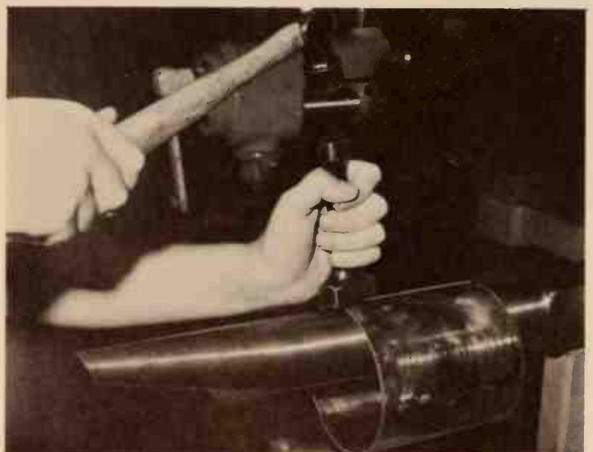


Fig. 5-32. A hand groover.

Fig. 5-33. Top, Locking the end of a seam. Fig. 5-34. Bottom, After both ends have been locked, complete the seaming operation by working back and forth across the seam, striking the groover moderate blows.



USING A ROTARY MACHINE

A rotary machine consists mainly of a rigid cast iron frame fitted with shafts, gears, and several different sets of rolls, Fig. 5-35. This machine can be set up to perform beading, crimping, burring, wiring, and turning. To save time, some shops are equipped with a separate machine for each operation so the rolls do not have to be changed.

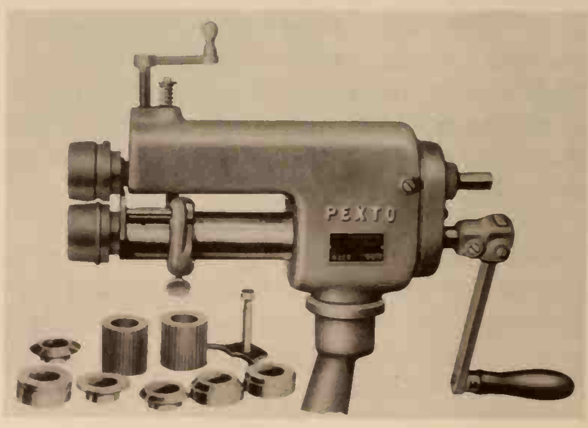


Fig. 5-35. A combination rotary machine with several sets of rolls.

Wiring an edge on a rotary machine is accomplished by setting the machine up with various sets of rolls. Following is the procedure:

1. Determine the size of wire to be used.

2. Lay out stock, making allowance for the material needed to make the wired edge. The amount of extra stock needed for 22 ga. or lighter is equal to 2-1/2 times the diameter of the wire. For example, if the wire is 1/8 in. in diameter: 2-1/2 x 1/8 in. = 5/2 x 1/8 = 5/16 in.--the additional amount of stock required.
3. Cut stock to correct size. The edge to be wired must be perfectly straight.
4. Install the turning rolls on the rotary machine, Fig. 5-36.

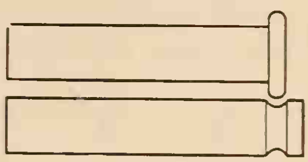


Fig. 5-36. A set of turning rolls.

5. Measuring from the center of the groove in the lower roller, set the gauge, a distance equal to two and one-half times the diameter of the wire.
6. Place the metal between the two rolls with the edge firmly against the gauge, Fig. 5-37a.

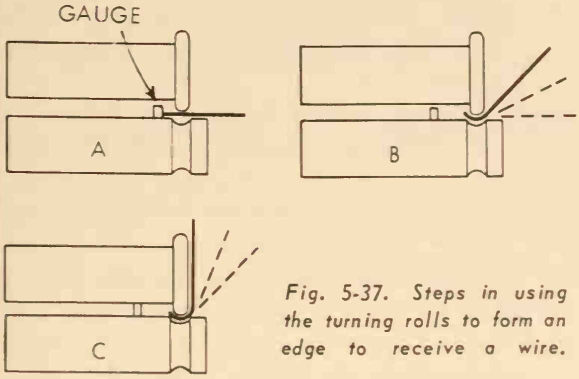


Fig. 5-37. Steps in using the turning rolls to form an edge to receive a wire.

7. Tighten the upper roll until it grips the metal. Turn the hand crank and feed the metal through the rolls until one complete turn has been made. Guide the metal carefully so the groove is even.
8. Lower the upper roll by tightening the crank screw about one-eighth of a turn. Tilt the work upward slightly as in Fig. 5-37b. Turn the crank until another complete revolution has been made.
9. Continue tightening the upper roll after each pass. Tilt the body of the work a little higher with each pass until a U-shaped groove is formed, Fig. 5-37c.

The next step is to install the wiring rolls, Fig. 5-38, on the machine and close the wired edge by following this procedure:

1. Select and cut a piece of wire of the correct diameter and length.
2. Adjust the gauge a distance from the sharp edge of the upper roll equal to the diameter of the wire, plus twice the thickness of the metal.
3. Insert the wire in the seat formed with the turning rolls. Shape the wire so it will fit in the seat easily.

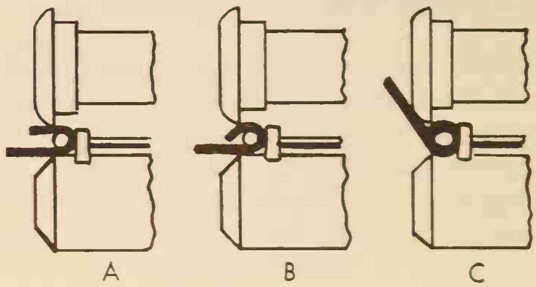


Fig. 5-38. Closing a wired edge.

4. Place the article to be wired between the rolls, with the wired edge up, and against the gauge, Fig. 5-38a. Lower the upper roll until the roll grips the work firmly.
5. Turn the crank until the edge being wired has traveled through the rolls.
6. Lower the upper roll a little farther and feed the work through again. Continue this procedure until the metal is folded firmly around the wire. On the last pass, tilt the work upward

slightly to force the edge of the metal under the wire.

7. Loosen the upper roll and remove the work.

Burring rolls which are generally furnished with a rotary machine, are used to turn a flange on a cylinder, and to turn a burr on a bottom in making a double seam to attach to a cylinder, Fig. 5-39a. The

Fig. 5-39. (A) Turning a flange; (B) Beading.

beading rolls are used to decorate and strengthen the sides of sheet metal projects, Fig. 5-39b.

FASTENING SHEET METAL

There are several methods used to join sheet metal pieces together. You will want to become familiar with some of the most common processes by using them when you construct your projects. Procedures are given in this unit for riveting, soldering and the use of sheet metal screws.

RIVETING

Rivets are used to join two or more sheets of metal together permanently. The rivets used are generally made of aluminum, copper or iron. It is customary to use rivets of the same metal as the parts that are being joined. Round head and flat-head solid rivets are more commonly used. Tinner's rivets are used on thin black iron, galvanized iron, and tin plate. They have flat heads and are made of soft iron or steel. They are usually coated with tin as a protection against corrosion. The sizes are designated by the weight of 1,000 rivets. The length of a tinner's rivet is proportionate to its weight and diameter, Fig. 5-40. All rivets of one size are the same length.

The following procedure is generally used when riveting sheet metal:

1. Select the rivets to be used. The size rivet depends on the thickness (gauge) of metal being joined and the diameter of the rivet shank. In general the rivet shank should extend from one to two diameters beyond the material. The diameter of the rivet should not be less than the total thickness of the pieces being joined.
2. Lay out the location for the rivets on the work-piece. All of the holes must

10 oz. 12 oz. 1 lb. 2 lb. 3 lb.

Fig. 5-40. Tinner's rivets (actual size).

be properly spaced and lined up. The spacing of rivets is determined by the type of material used and the nature of the work. For most practical purposes, a good rule is--minimum distance between rivets should be three diameters of the rivet shank, and the maximum, eight diameters. The distance from the edge of the work should be two diameters of the rivet shank.
3. Drill or punch the holes. Holes in thin metal are usually punched. Place metal over the end grain of a hardwood block or a lead block. Set the punch over the place where the hole is to be punched. Strike the punch solidly with a hammer to form the hole, Fig. 5-41. To be sure the holes in the pieces being joined will line up, drill or punch all of the holes in one of the pieces, and only one hole in the second piece. Join the two pieces with a rivet. Using the holes already drilled in the first piece as guides, drill the rest of the holes in the second piece.

4. Set the rivets. Place the rivet in the first hole with the head down on a flat, solid surface. If the work being riveted is cylindrical, place the rivet

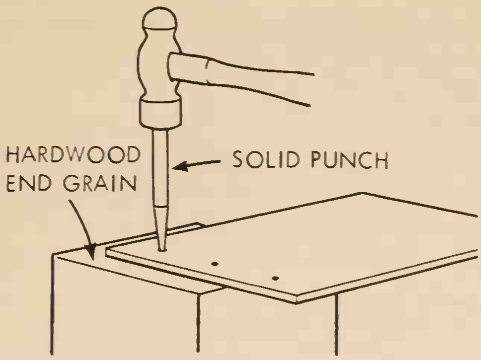


Fig. 5-41. Punching holes for rivets with a solid punch.

in the hole with the head of the rivet down on the crown of a stake. Place the hole of the rivet set over the rivet shank, Fig. 5-42a. Strike the rivet set with a hammer to flatten the sheet metal around the hole and draw the two sheets together. Keep the rivet set square with the surface of the sheet metal so it will not dent the work.

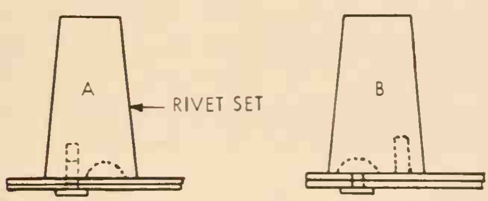


Fig. 5-42. (A) Setting a rivet; (B) Heading a rivet.

5. Head the rivet by striking the shank several direct blows with a hammer to expand the shank slightly beyond the hole. Form the head of the rivet by placing the cone-shaped depression of the rivet set in a vertical position over the shank. Then strike the rivet set with a hammer several times to round off the head, Fig. 5-42b. Be careful not to dent the sheet metal with the rivet set.

SHEET METAL SCREWS

Sheet metal screws are used in sheet metal work to join and install duct work for heating, ventilation, and air-conditioning. Many of our appliances are covered with sheet metal cases which are joined with sheet metal screws. These screws are known in the trade as self-tapping screws since they cut their own threads in mild and soft sheet metal. They are available in both sharp and blunt ends, Fig. 5-43. The blunt-end screws are generally found to be most satisfactory, but the pointed type is used if alignment of holes is difficult. The

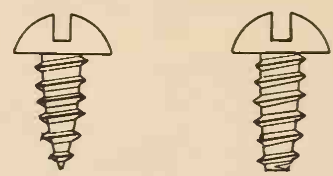


Fig. 5-43. Sheet metal screws. Left. Type A with sharp point. Right. Type Z with blunt point.

sharp pointed screws are generally used to join material which is lighter than .050 in. thick. The blunt end screws are used for sheets from .015 to .203 in. thick. Sheet metal screws are available in several head shapes with either slotted or Phillips recessed heads.

Procedure for using sheet metal screws:

1. Lay out the holes and prick punch the locations.
2. Choose the correct size drill, Fig. 5-44 and Fig. 5-45. The drill size should equal the root diameter of the screw. Drill the hole.
3. Line up the hole and start the screw. Be sure the two pieces of metal are held together firmly. Then fasten the screw in place with a screwdriver.

SOFT SOLDERING

Soldering is the process of fastening two or more pieces of metal together by

means of an alloy (solder) having a lower melting point than that of the pieces being joined. Soft solders are made of varying percentages of tin and lead. The most common compositions are 40/60, 50/50, and 60/40, (the first number mentioned is always tin). A good all-round solder contains 40 per cent tin and 60 per cent lead. This solder becomes completely liquid and mobile at 460 deg. F. Some craftsmen prefer 50/50 solder, also called "half and half." 50/50 solder becomes completely molten at 414 degrees F. Solder is available in bars, solid wire, and acid or rosin-core wire. The last two types of solder have the flux in the center of the wire.

Screw Size	Metal Thickness	Drill Size No.
	.018	44
	.024	42
No. 4	.030	42
	.036	40
	.018	39
	.024	39
No. 6	.030	38
	.036	36
	.018	33
	.024	33
No. 8	.030	32
	.036	31
	.018	30
	.024	30
No. 10	.030	30
	.036	29

Fig. 5-44. Recommended drill sizes for self-tapping, sharp pointed sheet metal screws.

Screw Size	Metal Thickness	Drill Size No.
	.018	44
	.024	43
No. 4	.030	42
	.036	42
	.018	37
	.024	36
No. 6	.030	36
	.036	35
	.024	32
No. 8	.030	31
	.036	31
	.024	27
No. 10	.030	27
	.036	26

Fig. 5-45. Recommended drill sizes for self-tapping, blunt end sheet metal screws.

Fluxes are used to remove oxide from the metal, and to prevent the formation of new oxide. Flux also lowers the surface tension of the molten solder so it will flow easily and penetrate where it should. There are two classes of fluxes, corrosive and non-corrosive. The corrosive works best but must never be used on electrical connections. Corrosive flux must be washed from the metal with warm water after soldering. The non-corrosive flux is used for all electrical work. There are many commercially prepared liquid, powder, and paste fluxes available. These work very satisfactorily for school shop purposes when used as directed by the manufacturer.

Soldering requires a source of heat. A common method used to transmit heat to the metal surface being joined is by means of a soldering copper, Fig. 5-46. The working end of this tool is made of copper because it is an excellent conductor of heat. Soldering coppers are available in several weights. A copper weighing 1/2 lb. is best for light work, a 1 lb. copper for medium work, and a 1 1/2 lb. copper for heavier jobs. A gas bench furnace can be used to heat the soldering copper, Fig. 5-47. An electric copper with interchangeable tips is very convenient for light work and is especially good for soldering electrical connections, Fig. 5-48.

Fig. 5-46. A soldering copper.

Soldering coppers must be tinned before they will do a good job of soldering. After a soldering copper has been used for some time, or if it has been overheated the point becomes covered with oxide. This

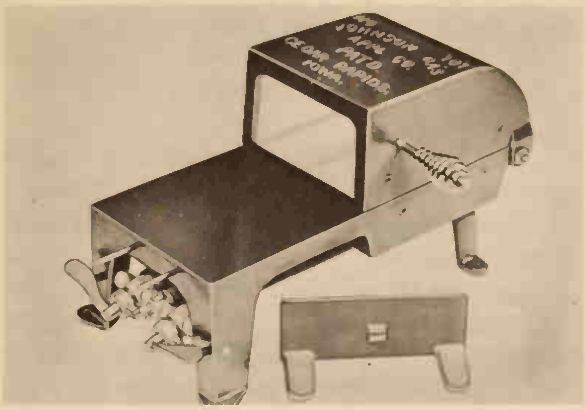


Fig. 5-47. A gas bench furnace. (Johnson Gas Appliance Co.)

oxide prevents the heat from flowing to the metal. To tin a soldering copper follow this procedure:

1. File the faces of the point with a mill

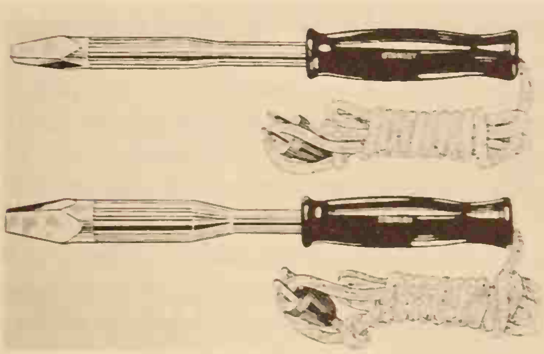


Fig. 5-48. Electric soldering iron.

SAMMY SAFETY
Says:

"Avoid breathing fumes from the sal-ammoniac---they cause headaches and injure the lungs."

file until they are smooth, flat, and clean, Fig. 5-49.
2. Heat the copper until it is hot enough to melt the solder.
3. Rub the faces of the point on a sal-ammoniac block while the point is hot.
4. Apply a little solder to the point as it is rubbed on the sal-ammoniac. A thin, bright film called tin will form on the point if the copper is not overheated.
5. Remove any excess molten solder from the point with a rag.

Liquid flux can be used instead of the sal-ammoniac for tinning by dipping the

Fig. 5-49. Cleaning the point of a soldering copper.

point into the flux and rubbing it with solder.

The following procedure should be followed to insure a strong, neat soldering job:

1. Clean the surfaces to be soldered. Solder will not stick to dirty, oily, or an oxide coated surface. Liquid cleaner can be used to clean a dirty surface. Remove oxide from the metal with abrasive cloth.
2. Use a properly tinned copper.
3. Keep the surfaces to be joined close together to insure a strong bond, seam, or joint.
4. Flux only the area to be soldered. Be

sure to use the proper flux for the job.

5. Heat the soldering copper to the proper temperature. Copper should be hot enough to melt solder readily. Do not allow it to become red-hot.
6. Tack the seam or joint by applying solder at several points. This is done by placing the point of the soldering copper on the metal where it is to be tacked. Hold it there until the flux sizzles. Then apply a small amount of solder to the metal directly in front of the point of the copper.
7. Place one face of the copper flat against the metal at one end. Hold it there until the solder melts, Fig. 5-50.
8. Draw the copper SLOWLY along the seam or joint in one direction only,

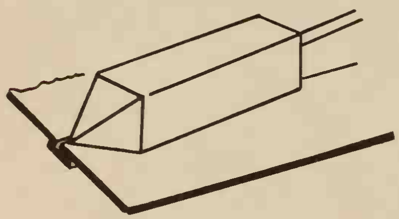


Fig. 5-50. Hold one face of the soldering copper flat against the surface of the metal.

flowing the solder on in front of the point. The soldered joint or seam will not be satisfactory if the solder is just "stuck on" or melted on.

9. Do not move or handle the soldered job until the solder has "set" and has partially cooled. Solder is brittle and weak during the process of solidification.
10. If an acid flux has been used, wash off all traces of the flux with running warm water.

Sometimes it is necessary to solder several thicknesses of metal together or to apply one piece of metal to another so the solder will not show. This is called <u>sweat soldering</u>. In sweat soldering, the contacting surfaces of the metal is coated with a thin, even coating of solder. The surfaces are then placed together and heated with a large copper or a torch until the solder melts. This "sweats" the pieces of metal together. Use plenty of flux and be sure the pieces being joined are clean.

QUIZ - UNIT 5

1. List three major building trades that employ sheet metal workers.
2. In sheet metal work a development or pattern is called a ---.
3. List three kinds of pattern development.
4. When cutting sheet metal that is 22 ga. or lighter you can use straight snips for --- cuts and to cut large -- curves.
5. Hawk -bill snips are used for making - - cuts.
6. A hatchet stake can be used to make --- bends.
7. A cone-shaped piece of metal can be formed over a --- stake.
8. List four sheet metal operations that can be performed on a bar folder.
9. What is the function of the back roll of a forming machine?
10. What is a hand groover?
11. Figure the amount of material needed to make a wired edge on a piece of 22 ga. metal, using 1/16 in. wire.
12. The diameter of a sheet metal rivet should not be less than the --- --- of the pieces being joined.
13. A --- --- is used to "head" a rivet.
14. Sheet metal screws are available in both --- and --- ends.
15. What size drill should be used for a No. 6, sharp pointed sheet metal screw, to join metal that is .030 in. thick?
16. List four forms of solders.
17. Why must the oxide which forms on the point of a soldering copper be removed?

FORGING

UNIT 6

1. Forming metal by forging.
2. Forging tools and equipment.
3. Hand forging procedures.

One of the earliest methods of forming iron was by hand forging. In hand forging, the metal is heated in a forge and shaped over an anvil with hammers and tools of various kinds. Today, industry has speeded up forging for production by using various kinds of machine-powered hammers or presses that are used instead of hand sledges. These machines can forge such items as tools, axles, and crankshafts for an automobile engine. Some of the jobs in a forge shop require skill in the operation of power hammers. People who operate power hammers are called hammersmiths. The hammer which moves up and down under power shapes the heated metal. The hammersmith controls both the strokes of the hammer and the movement of the metal as it is shaped.

Drop hammermen use machines which have accurately machined dies between which the heated metal is pounded into shape. These machines are used when producing large quantities of pieces. Blacksmiths repair tools and equipment of various kinds by hand forging. They can use all types of hand forging tools and equipment. Heaters heat the metal to the correct temperature and inspectors check the forged articles.

You will find hand forging a very interesting area of metalwork. There is something fascinating about hammering red-hot steel which is soft and plastic. You will also find forging useful in making repairs on metal parts around the home and in the shop.

THE FORGE

A forge is used to heat the metal to be shaped. It may be a gas or oil-fired furnace, or a coal forge, Fig. 6-1. To light a gas or oil furnace, place a lighted piece of paper in the fire box close to a burner.

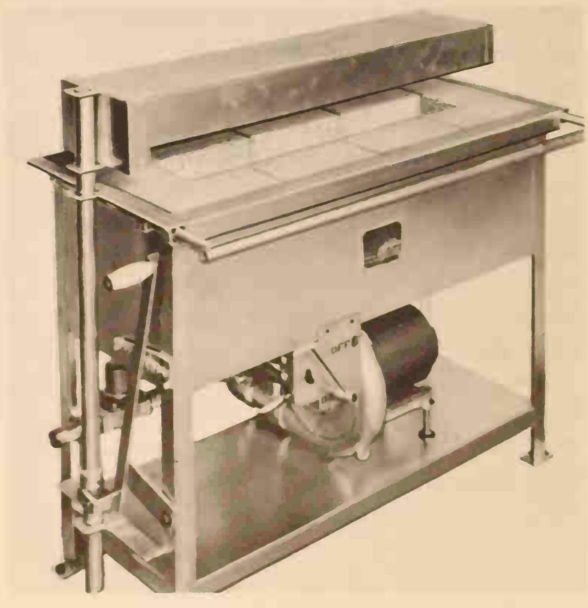


Fig. 6-1. A gas fired forge. (Johnson Gas Appliance Co.)

Turn on a small amount of air and then a little fuel until the furnace lights up. As the furnace heats up, turn on more fuel and air until the flame is blue. Too much air causes the formation of a heavy scale on the metal being forged. When you are through using a forge, close the gas and air valves.

ANVIL

Metal is hammered and bent into shape on an anvil, Fig. 6-2. The size of an anvil is determined by its weight. Commonly used sizes weigh from 150 lbs. to 300 lbs. A 100 to 200 lb. anvil is suitable for school use. Most anvils have either a cast steel, or cast iron body. The face is made of hardened steel welded to the body. It is smooth and should be kept free of dents and marks. The horn which is shaped like a cone is unhardened but tough. It is used for shaping rings, hooks, and curved parts. The cutting block which is located between the face and the horn, has a soft surface. It is used when cutting or chipping metal with a cold chisel--do not use the face for these operations. The hardy hole is square. It is used to hold square shank tools such as hardies, swages, and fullers, Fig. 6-3. The pritchel hole is used for bending small rods and punching holes in metal.

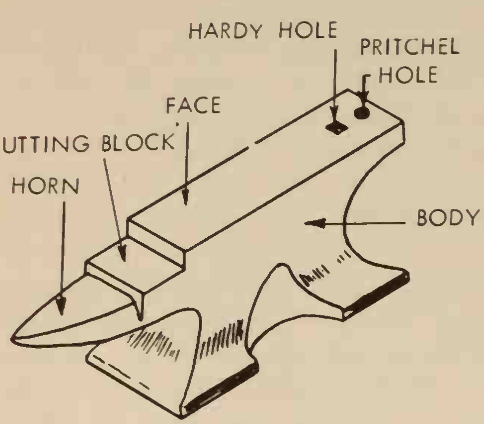


Fig. 6-2. The parts of an anvil.

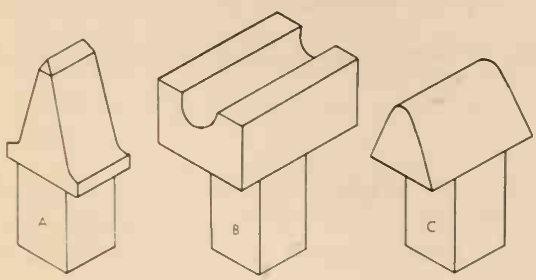


Fig. 6-3. Anvil tools. (A) Hardy to cut hot and cold metal; (B) Swage to smooth round stock (they are made in pairs---the one that goes on top has a handle); (C) Fuller, to form depressions in heated metal (they are also made in pairs).

HAMMERS

Hammers and sledges of different types are used in hand forging, Fig. 6-4. The size of a hammer is given in ounces or pounds. The most common sizes found in school shops are: the ball peen, 6 oz. to 2 1/2 lbs.; and the cross and straight peen blacksmith's hand hammers, 1 1/2 to 3 1/2 lbs. These hammers are usually made of forged steel, hardened, and given a polished finish.

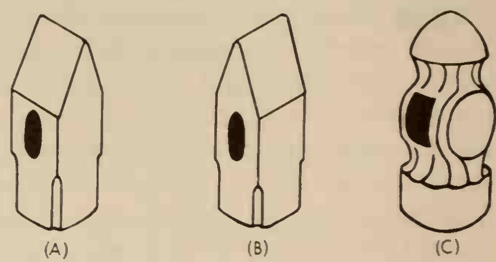


Fig. 6-4. Forging hammers. A-Cross peen; B-Straight peen; C-Ball peen.

SAMMY SAFETY
Says:

"Do not look into the opening of the furnace as the fuel is turned on. Do not operate the forge until your teacher shows you how.

Wear a face shield when hammering hot metal. The scale that flies is hot. Wear gloves when necessary and use tongs when handling hot metal. Wear an asbestos glove on the hand holding the stock. If the piece of metal is too short to hold by hand safely, grip it with tongs."

FORGING PROCESSES

The metal must be heated to the correct temperature for shaping. Most mild steel should be heated to a good bright red.

Thinner pieces of metal require less heat than thicker ones. Tool steel should be heated to a point between cherry red and orange. Never allow the metal to become so hot that sparks fly from it, since this causes the metal to oxidize and burn. Never hammer on tool steel after it loses the orange color and starts turning black since this will cause the metal to crack. All forging must be done at forging temperature, also with as few heatings as possible, because too much heating spoils the steel. Study each forging operation before starting, and have all the tools handy so when the metal is hot, hammering and forging can be done quickly.

HOLDING WORK

The metal to be forged must be held securely while it is being worked. A pair of tongs of suitable size and shape is used for this purpose. There are several sizes

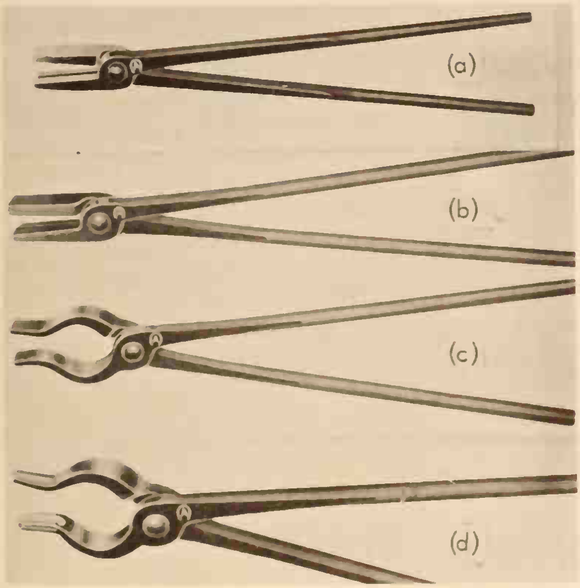


Fig. 6-5. Forging tongs: (A) Straight lip, with "V" notch in each jaw; (B) Straight lip; (C) Single pick up; (D) Curved lip, with fluted jaws. (Stanley Tools)

and shapes, but the most common are illustrated in Fig. 6-5. The straight-lip tongs that have a "V" notch in each jaw are used to hold square and round shapes, 6-5a. The other pair of straight-lip tongs is used to hold thin flat work, Fig. 6-5b. Single pick up tongs are designed for picking up either flat or round stock, Fig. 6-5c. The curved-lip tongs, with fluted jaws are used to hold bolts and irregular-shaped pieces, Fig. 6-5d. The jaws of the tongs must close evenly on the stock throughout their length, Fig. 6-6. If tongs of

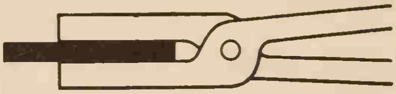


Fig. 6-6. Tongs gripping piece properly.

suitable size are not available, slight adjustments can be made by heating and bending the jaws so that they close evenly on the stock.

UPSETTING METAL

The purpose of upsetting is to increase the thickness of the stock at a given point. This operation shortens the length of the piece so be sure to allow enough extra stock. To perform the upsetting operation, place the stock in the fire in a position that will heat the portion to be upset to a yellow heat. If the metal is long enough, pick it up with one hand and place the heated end on the face of the anvil, Fig. 6-7.

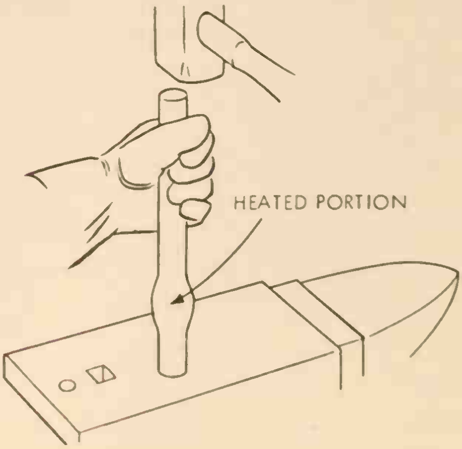


Fig. 6-7. Upsetting a piece of metal.

Working rapidly, strike the cold end of the stock hard blows with a heavy hammer. If the stock bends, lay it flat on the anvil and straighten it with the hammer. Then continue the upsetting process until the desired thickness is obtained. If the stock becomes hard to work because of cooling, reheat it and continue the process. When the stock upsets too quickly at the end, dip it in water and proceed in the usual manner.

DRAWING OUT

In forging, drawing out stock means to lengthen the piece and to reduce a portion of it in size. The tapered part of a flat cold chisel is an example of drawing out metal. When forging mild steel, heat the portion to be worked to a bright yellow heat. Then quickly place the part to be drawn on the face of the anvil. Hold the piece firmly with tongs and strike the metal a few heavy blows, Fig. 6-8. Hold the hammer

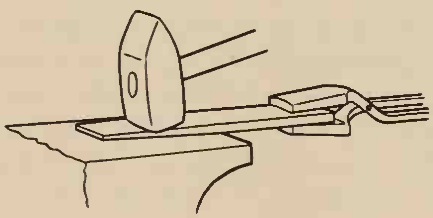


Fig. 6-8. Drawing out metal.

so that its face is parallel with the surface of the work piece when the blow is struck. Continue the drawing out process, rotating and striking the metal first on the broad face and then on the edge until the desired shape is obtained. While drawing out the metal each broad face should be hammered alternately. When drawing out metal to a round point as on a center punch, follow the steps shown in Fig. 6-9.

BENDING

To make a sharp bend, heat the stock at the point where the bend is to be made. Place the stock on the anvil face with the portion to be bent down at the edge of the anvil. Strike the extended portion moder-

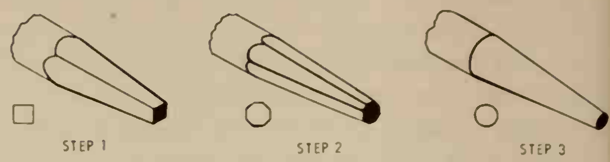


Fig. 6-9. Steps in forging the point of a center punch.

ate blows with the hammer to bend the stock down to the desired angle, Fig. 6-10. Angular bends can also be made in the hardy hole or pritchel hole of the anvil. Bars can often be bent in a vise. Thin

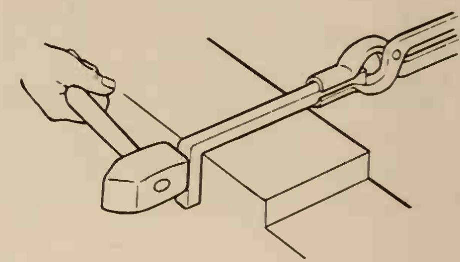


Fig. 6-10. Forging a sharp bend on the anvil.

metal can be bent cold; heavy pieces must be heated.

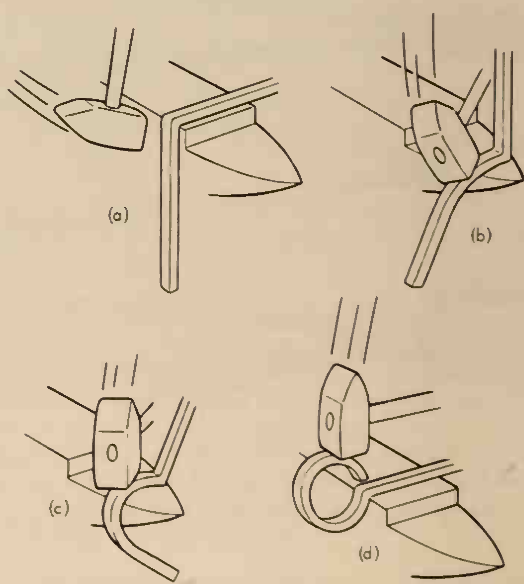


Fig. 6-11. Steps in forging an eye.

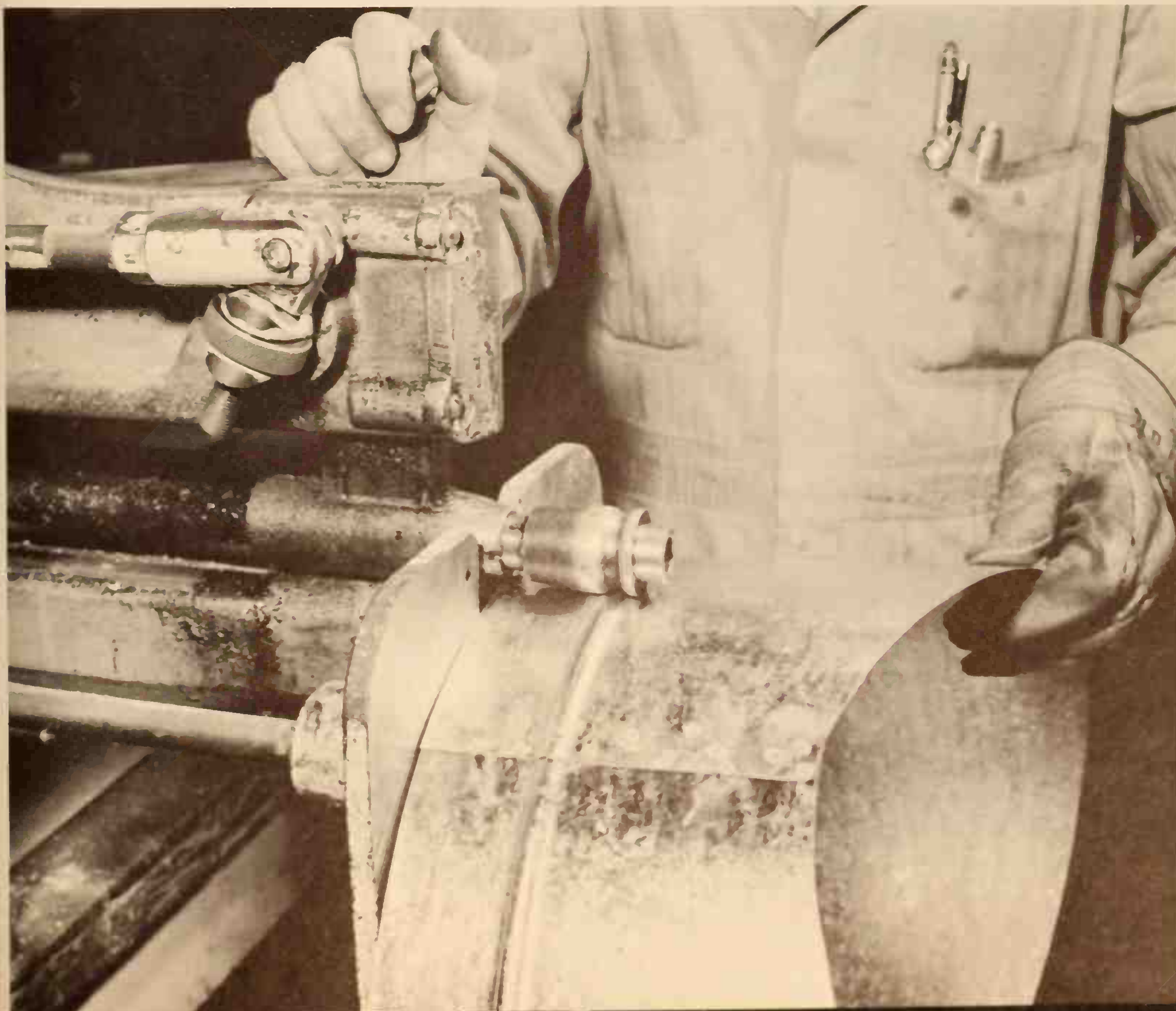
FORMING AN EYE

Measure the length of metal it will take to make the eye, and mark the point with a prick punch. Heat the metal at this point, and bend it over the edge of the anvil to a 90 deg. angle, Fig. 6-11a. Heat and start bending the end to form the eye, Fig. 6-11b. Continue by heating and forming the eye over the anvil horn, Fig. 6-11c. Close the eye by holding it over the edge of the anvil, and striking it with a hammer, Fig. 6-11d.

QUIZ - UNIT 6

1. What is forging?
2. What is the difference between production forging and the work of a blacksmith?
3. List the steps in lighting a gas forge.
4. What safety precautions should be followed when lighting the forge?
5. What are the parts of an anvil?
6. What is the proper heat for forging tool steel?
7. What is meant by drawing out metal?
8. What is the procedure for upsetting metal?
9. What are the steps for forming an eye?
10. List two safety precautions to be followed when doing hand forging.

Beading operation on ventilator collar---fabricating plant of Butler Steel Products Co.



HEAT TREATMENT OF STEELS

UNIT 7

1. How to anneal, harden, and temper steel.
2. How to determine different temperatures by colors of heated metal.
3. How to caseharden low-carbon steel.

Heat treating is a process of heating and cooling steel in certain ways to change its properties. By properly heat treating, metals can be made harder and tougher. After you have made a cold chisel, center punch, screwdriver blade or any small tool, it will be necessary to heat treat it to make it useful. If the tip of a screwdriver blade, for example, is too hard it will be brittle and chip off when used. If the tip is too soft it will bend, so to be useful the tip of the blade must be heat treated. Tools must have a certain hardness, toughness, and brittleness to do their work. To obtain these characteristics there are four principal operations which may be performed to properly heat treat a piece of steel for its particular use. These operations are: Hardening, Tempering, Annealing and Casehardening.

HARDENING

Hardening is a process of heating steel to a certain temperature and then quenching (cooling) it in a suitable medium such as water, oil, or brine, depending upon the type of steel being hardened. Hardening is done in a furnace heated with oil, gas, electricity, or solid fuel. The steel is first heated to the desired temperature above the critical range in order to get the correct grain structure, and is then cooled quickly in a quenching medium in order to preserve this structure. Steel companies can supply information concerning temperatures and quenching procedures for their steels. This information is also given in Machinist's Handbooks. The temperature can be checked with a pyrometer attached to the furnace, a magnet, or by observing the color. A pyrometer, which is an electric thermometer, accurately registers the temperature in the furnace. Steel is magnetic until it reaches the critical temperature, then it is non-magnetic. When using this method, heat the metal until the magnet stops picking it up. The metal should then be suddenly cooled. Determining the temperature by observing the color of the hot metal is not too accurate. However, the old time heat treater used this method for many years.

The hardness depends upon the amount of carbon in the steel, the temperature of the heated steel, and the speed of cooling.

TEMPERING

Tempering is a process which is used to remove a certain degree of hardness and brittleness of steel and increase its toughness. Tempering is also referred to as drawing the temper. Hardened steel breaks easily and is too hard and too brittle for many tools. Therefore, it is necessary to remove some of the hardness by softening the metal. Steel can be tempered using the color method as a guide to the proper temperature. The temper is gauged by the colors formed on the surface as the heat increases, Fig. 7-1. A modern method which is used when a quantity of pieces are to be tempered, is to place the hardened metal in a bath of molten lead, heated oil, or other liquids and heat them to the required temperature. The metal is then removed from the bath and quenched. The

bath method does a more uniform job of tempering, and the temperature can be held to close limits.

Degrees Fahrenheit	Colors For Tempering
440	Yellow
460	Straw-yellow
470	Straw
500	Brown
520	Brown-purple
540	Purple
570	Blue

Fig. 7-1. Colors for tempering.

ANNEALING

Annealing is the opposite of hardening. It is a process of softening steel to make it easier to machine, cut, stamp, or shape, and to relieve stresses and hardness resulting from cold working. In annealing, the metal is cooled as slowly as possible. The slower the cooling, the softer it is when cold. To anneal steel, heat it slowly to the critical temperature. Cool it slowly by packing it in hot ashes to keep the air away or it may be cooled off with the furnace.

CASEHARDENING

Casehardening is the hardening of the outer surface of metal. Only low-carbon steel and wrought iron can be casehardened. This process adds a small amount of carbon to the case (outside) of the metal part so it can be heat treated and made hard. The center, or core of the metal remains soft. Casehardening is done to parts which need a hard wearing surface such as gears, screws, hand tools, and roller bearings. Industry uses several methods to caseharden parts. Cyaniding is a common one and is done by placing the metal in a bath of molten cyanide. This method is too dangerous however for school shops. Carburizing is another method. This work is placed in a metal box containing a mixture of bone, leather, charcoal, and carburizing materials. The container is then sealed and heated to about 1650 deg. F. so the piece soaks up the carbon and forms a high carbon case on the outside. The piece is cooled in the carburizing box. Take the piece out of the container, reheat it to the critical temperature and quench.

HEAT TREATING PROCEDURE

Many of the projects made in the school shop require heat treatment. Cold chisels, center punches, hammer heads, and small parts can be heat treated very successfully with inexpensive equipment. The source of heat can be a small gas or oil-fired furnace, Fig. 7-2, blowtorch, forge, gas welding torch, or a bench soldering furnace. The quenching bath can be a pail of water,

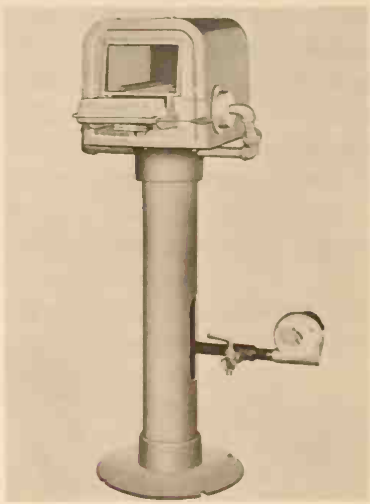


Fig. 7-2. A gas fired heat treating furnace that will reach 2300 deg. (Johnson Gas Appliance Co.)

tempering oil, or brine, depending on the type of metal. Forging tongs can be used to hold the hot metal.

The tool steel used in most school shops is a water-hardening type. It is generally in an annealed state ready for cutting, drilling, filing, or machining. If it becomes necessary to heat the metal for certain operations, you will have to

anneal it again if more cutting or shaping has to be performed. Annealing, hardening, and tempering operations may occur as a series of steps in the heat treatment operations, or annealing may be a separate process to remove internal strain developed while the metal is worked. Hardening may be done without performing either of the other processes. Tempering always follows annealing and hardening. Following is the procedure you may use to heat treat shop projects:

ANNEALING

1. After the piece has been forged to shape, heat it throughout the portion to be annealed. A moderate flame should be used if gas is the source of heat.
2. Turn the metal as it is heated until it reaches a cherry red or the color just below the critical range of the steel being annealed.
3. Remove the metal from the heat and cover it immediately with pulverized coke or air slaked lime. Keep the metal covered until it is cold.

HARDENING

1. Heat the metal to its critical temperature. For example, .70 to .90 carbon, water-hardening, tool steel is heated to about 1450-1550 deg. F. The color closest to this temperature is a cherry red to a bright red, Fig. 7-3. Be sure to have the metal heated uniformly.
2. Quench the metal quickly in the correct cooling solution. Whirl the metal around in the solution so it will cool quickly and evenly, Fig. 7-4. Water is used for most tool steels. The temperature of the water should be between 60 to 80 deg. F.
3. Check the metal for hardness by running a new file across a corner or edge. If the metal is hard, the file will not cut in.

Deg. F	
752	Red heat (visible in the dark)
975	Red heat (visible in the daylight)
1292	Dark red
1472	Dull cherry-red
1652	Cherry red
1832	Bright cherry red
2190	Lemon yellow
2300	White
2500	Welding heat (sparks fly)

Fig. 7-3. Colors for judging high temperature.

TEMPERING

The entire piece of metal can be tempered by heating it in a furnace to the

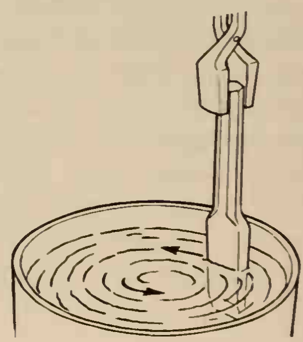


Fig. 7-4. Quenching heated steel. Whirl the metal in a circular motion, with a slight up and down movement at the same time.

temperature which will produce the degree of toughness and hardness desired, Fig. 7-5. Remove the piece and cool it quickly in the correct quenching solution.

To draw the temper on small tools such as center punches, screwdriver blades, or cold chisels, the following procedure may be used:

1. Harden the entire tool.
2. Polish about one inch of the surface at the cutting edge or point with abrasive cloth. This will make it easier for you to see the change of colors as the heat travels toward the

point or cutting edge of the tool.

3. Heat the metal slowly and uniformly back of the polished surface. Watch carefully for the colors as they travel toward the hardened end. The colors generally appear in the following order--pale yellow, straw color, light brown, light purple, blue-red, blue, and finally gray.
4. When the proper color appears at the cutting edge or point, plunge the metal into the quenching solution quickly, and move it in a circular motion until completely cooled.
5. Check the tool for hardness by using it on a scrap piece of metal. If the piece chips, it is too hard and must be heated to a color of a slightly lower degree of hardness

Deg. F.	Color	Tools
430	Pale yellow	Hammer faces, Scribers, Scrapers.
460	Straw yellow	Center punches
500	Brown	Cold chisels
540	Purple	Screw drivers

Fig. 7-5. Tempering colors for common tools.

and cooled as before. If the point or edge bends under practical use, it is too soft and must be hardened and tempered again.

The Sand Box method is another way which can be used to temper small pieces. This is done by placing the hardened tool (polished as described in Step 2) in the sand with the point sticking out. Heat the sand in the bottom of the metal box. Watch the temper colors as they travel toward the point. When the correct color reaches the point, remove the tool with tongs and cool it quickly.

Hardening and tempering may be performed with one heat. This is done by heating the metal to the proper tempering temperature. Remove the tool from the heat, and quickly clean the point with abrasive cloth. Then insert the tool in the cooling solution and remove it quickly. Watch the colors carefully as they appear. When the proper color appears at the work end, quickly plunge the tool in the cooling solution and move it around in a circular motion, with a slight up and down motion. The up-and-down motion helps prevent fractures or checks at the line where the tool is placed in the cooling solution.

CASEHARDENING

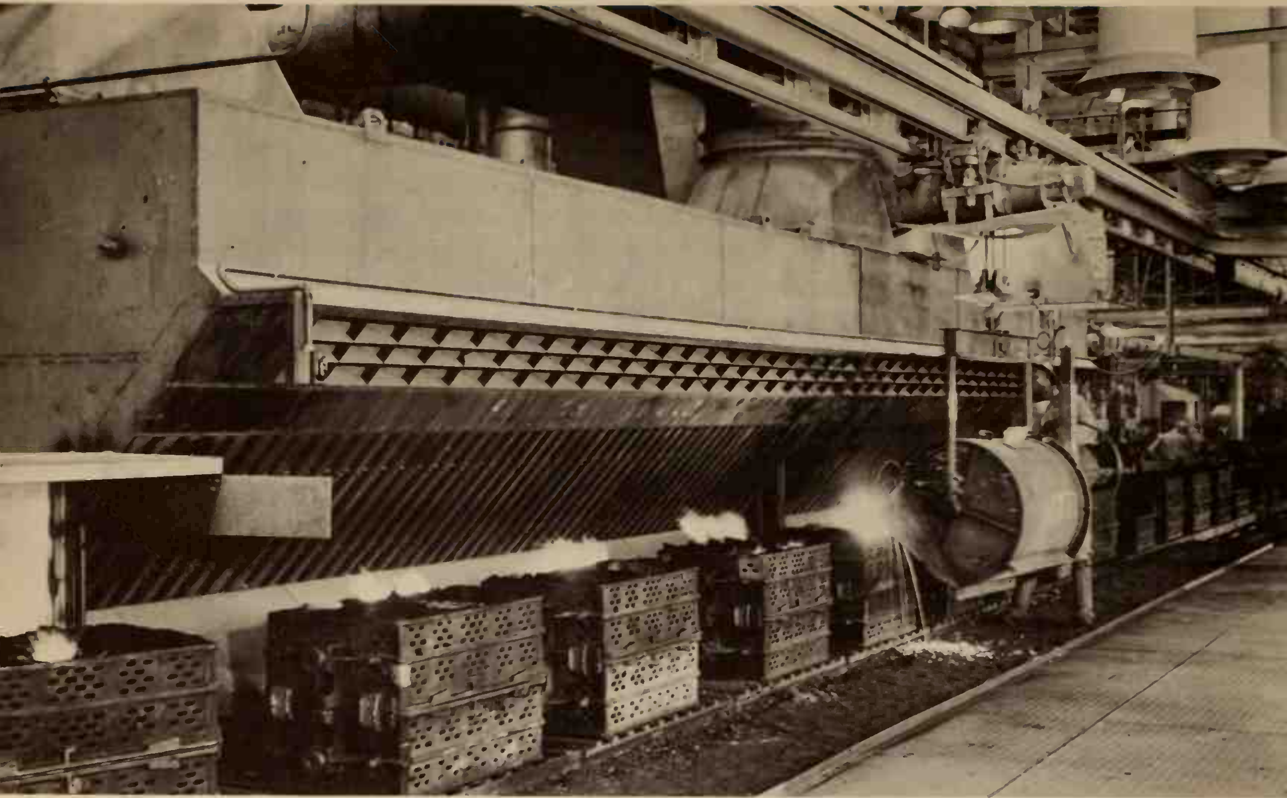
1. Place the pieces to be casehardened in metal boxes or pipes.
2. Pour Kasenite (a non-poisonous commercial compound) around them. Be sure the pieces are completely surrounded with the compound.
3. Place the lid on the box and put it in the furnace.
4. Heat the box to about 1650 deg. F. The depth of casehardening will depend upon the length of time the part is kept hot. A depth of approximately 1/32 in. is obtained if the packed metal is held at the above temperature for about four hours.
5. Remove the box from the furnace and allow it to cool.

SAMMY SAFETY
Says:

"When working with hot metal be careful not to burn yourself or another person. Always wear protective clothing."

6. Reheat the parts to about 1600 deg. F. and quench in water. This will give the metal a hardened case and leave the core soft.

Simple casehardening can be done by heating the metal to a bright red and placing it in a container filled with a com-



Hot metal pouring operation at Ford Motor Company's foundry in Cleveland, Ohio.

mercial hardening compound. Roll or move the metal around in the compound. The compound will melt and adhere to the surface of the metal, forming a hard coating of steel around it. Reheat the metal to a bright red color and plunge it into clean, cold water. If a deeper case is desired, repeat the above steps.

HEAT TREATING OCCUPATIONS

The heat treating process is highly scientific and procedures vary with the many kinds of metals being used in industry. The heat treater must have a knowledge of chemistry and physics. Industries where foundry, forging, and machining of metal is done require the services of skilled heat treaters. Today most of the heat treating is automated; however, the technicians, engineers, and inspectors are responsible for obtaining the correct metal characteristics with the automatic equipment.

QUIZ - UNIT 7

1. Why is it necessary to heat treat a cold chisel?
2. List the three characteristics tools should have to do their work.
3. How is tool steel hardened?
4. Describe one method for drawing the temper on a center punch.
5. Three cooling solutions are ---, ---, and ---.
6. Steel is magnetic until it reaches the --- temperature.
7. Tempering tool steel removes a certain degree of --- and ---.
8. Why does hardened steel have to be tempered for many tools?
9. Describe how tool steel is annealed.
10. Tempering always follows --- and ---.
11. Why should the metal be moved in a circular motion in the cooling solution?
12. Can hardening and tempering be performed with one heat?
13. What is casehardening?
14. Are all steels of the water-hardening type?
15. The pack method of carburizing is a method used to --- metal.

FOUNDRY

UNIT 8

1. Principal methods of casting metal.
2. Some of the characteristics of a good pattern.
3. How to make a core.
4. How to make a sand mold.

The foundry process is a vital link in the chain of metal industries. Most of the metal products we use every day contain some cast parts. The automobile, bicycle, refrigerator, plumbing fixtures, and many other items around the home have foundry made parts. Founding is a process of producing metal objects by pouring molten metal into a hollow mold made usually of sand. Articles produced by founding are called castings.

Founding provides many jobs for laborers, semi-skilled workers, skilled workers, technicians, and engineers. The engineer and the metallurgist are responsible for controlling the quality of the metal required for the objects to be cast. Highly skilled woodworkers and metalworkers, called patternmakers, make the patterns. Molders ram up the molds. Coremakers are a specialized group of workers who make the cores. The melter operates the furnace which melts the metal and the metal is poured into the molds by the pourer. Chippers, grinders, and finishers clean up the castings.

METHOD OF CASTING

Green sand casting is a method generally used in school shops. A material, consisting of a mixture of sand and clay is rammed into a mold. Molten metal is poured into a cavity formed in the sand mold. After the metal has solidified, the molds are broken up and the sand is used for another mold.

Permanent molds are used for producing large quantities of identical pieces. These molds are made of steel and they are used primarily for casting nonferrous metals such as aluminum, brass, and bronze.

Investment casting, which is sometimes referred to as lost wax casting, is used for casting jewelry, dental structures and parts requiring very close tolerances. In the process a wax pattern is coated with an investment powder which hardens forming a shell around the wax. The wax is then melted out leaving a cavity into which the molten metal is poured.

Die casting is a method of casting nonferrous metals in which the molten metal is forced into a steel mold or die under pressure. Castings can be made quickly and economically on automatic machines by this method. Die castings can be produced with finer finish, detail, and greater accuracy than ordinary sand castings.

A foundry in the school shop provides a means for making many interesting projects such as wall plaques, ash trays, lamps, candlestick holders, parts for home work shop tools, and machines to mention a few. By using a little imagination and creative ability, you will be able to design and make some very useful projects in this area.

PATTERNMAKING

Patterns are needed to form the cavity in the sand mold into which molten metal

is poured. They may be made of wood, metal, plaster of Paris, or wax. A metal pattern lasts longer and keeps its shape better. Metals commonly used are aluminum, cast iron, steel, and brass. Woods generally used for patterns are white pine, mahogany, cherry, maple, birch, and fir. White pine is usually preferred because it works easily, is readily glued, and is reasonably durable. Wood patterns should be varnished to protect them against moisture. Coloring powders can be added to the varnish to identify various parts of the pattern. You can probably find many articles around your home which may be used as patterns for foundry work. Small trays, plaques, paper weights, book ends, etc. make good patterns providing they have enough draft to be pulled.

Draft refers to the taper on a pattern that makes it possible to remove it easily from the sand mold, Fig. 8-1. If a pattern does not have enough draft, the mold

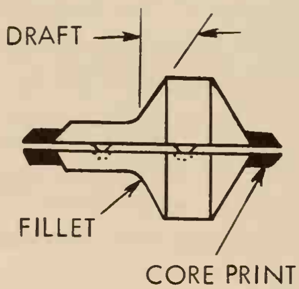


Fig. 8-1. Split pattern.

will break when the pattern is pulled. As a general rule each side should be tapered 1/8 in. for each foot of surface to be drawn. Fillets are used in sharp internal angles, Fig. 8-1. These fillets can be made of wax, leather, or wood.

Metal takes up more space when it is hot than when it is cold. Therefore, the pattern must be made larger to allow for this shrinkage. For example, cast iron shrinks about 1/8 in. to the foot, so the rule in reality would be 12 1/8 in. long. The additional length is gradually gained in the length of the rule. The shrinkage allowance varies with the kind of metal being cast, and the size and shape of the casting. To compensate for this contraction of the castings in cooling, the following allowances are made: cast iron 1/8 in. per ft., yellow brass 7/32 in. per ft., aluminum 1/8 to 5/32 in. per ft. If the cast piece is to be machined, the pattern should be large enough to produce a piece that can be cleaned up leaving no rough spots or flaws after it has been cut to size.

CORES

A core is used in molding to form a hole or hollow space in a casting, Fig. 8-2. Cores are made from washed silica sand

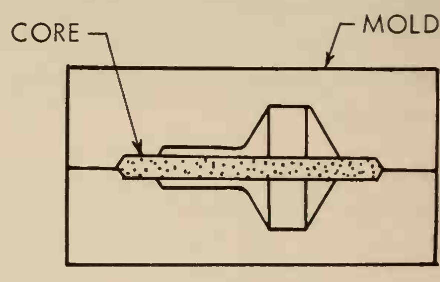


Fig. 8-2. Core in mold.

and a bonding material. The sand and binder is mixed until the binder is uniformly distributed in the sand. The core sand is molded to shape in a core box, Fig. 8-3. Core prints are provided on patterns to

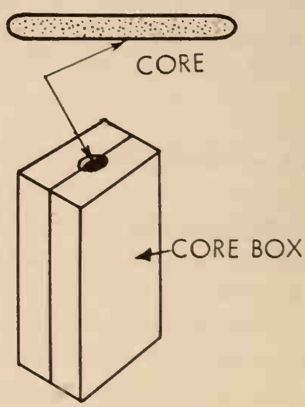
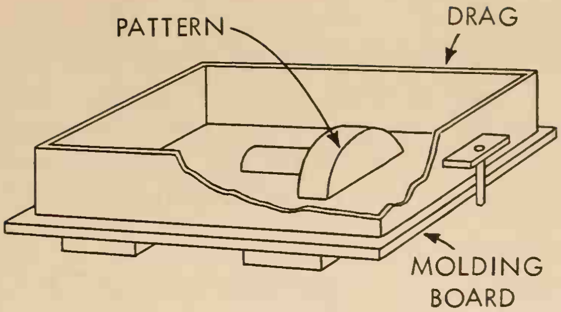


Fig. 8-3. Core box.



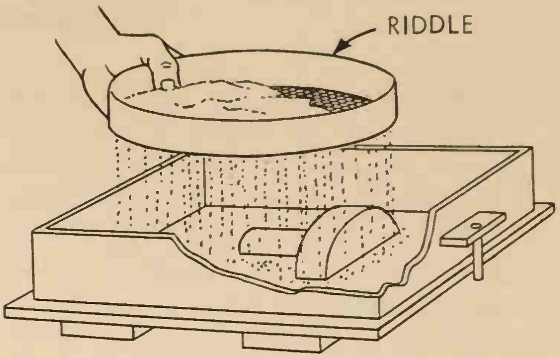


Fig. 8-4. Left, Pattern and drag placed on molding board.
Fig. 8-5. Right, Riddling molding sand over pattern..

form recesses in the mold to support the core, Fig. 8-1. The core is then turned out onto a plate and baked in an oven. The oven temperature and baking time depends on the size of the core and the kind of binder used. The temperature and baking time should be controlled to produce a core with enough hardness and strength to withstand the flow of the molten metal, as it is poured into the mold cavity around the core. Wires can be embedded in large cores to provide additional strength in sections requiring greater strength. Large cores should be vented to permit passage of mold gases. If the core has two or more parts that are to be assembled, they can be bonded together with a flour paste. To improve the surface smoothness, coat the core with a wash of either talc or graphite.

MAKING A SAND MOLD

1. Prepare the molding sand by mixing and tempering. To temper the sand, sprinkle it with a little water and mix with a shovel, until all the lumps have been removed. The sand is properly tempered if a lump squeezed in your hand remains in a lump, retains the sharp impressions of your fingers, and leaves the hand clean. When the lump is broken it should break with clean, square edges. If the sand sticks to your hand it is too wet. Properly tempered sand is necessary to get good castings. If the sand is too damp when the melted metal is poured into the mold, steam will form faster than it can escape through the pores of the sand.
2. Place the drag half of the flask on a molding board with the pins pointing down, Fig. 8-4. Place the pattern in the center with its flat side down on the board. Dust the pattern with just enough parting compound to cover its surface.
3. Set the riddle on top of the drag and fill it with sand. Riddle the sand over the pattern until it is covered 1 in. or more, Fig. 8-5.
4. Pour the rest of the sand left in the riddle into the drag. Shovel in more sand until the drag is heaping full.
5. Press the sand down in the drag and around the pattern with the peen end (small end) of the rammer, Fig. 8-6. The large end of the rammer is the

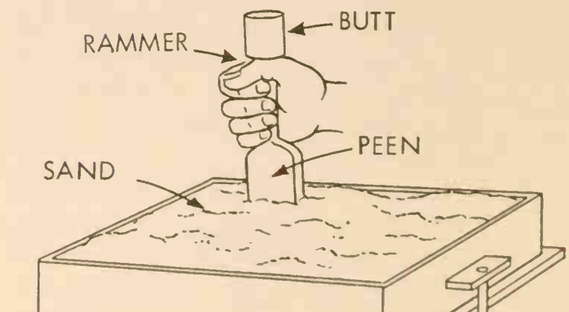


Fig. 8-6. Ramming the sand down in the drag and around the pattern.

butt. Be careful not to strike the pattern, or the edges of the drag. Ram the sand in firmly around the pattern, and drag with the butt end. Properly ramming the sand is very important. If it is not rammed enough the sand may not be packed around the pattern firmly enough to give a good, sharp impression. If the sand is rammed too tightly the pores will not be large enough to allow the hot gasses formed in the mold to escape.

6. Strike off the excess sand on the top of the mold with a strike bar, Fig. 8-7. Sprinkle a handful of sand over the mold and lay a bottom board on the top. Move the bottom board back and forth, pressing down at the same time, until it sets firmly against the edges of the drag.

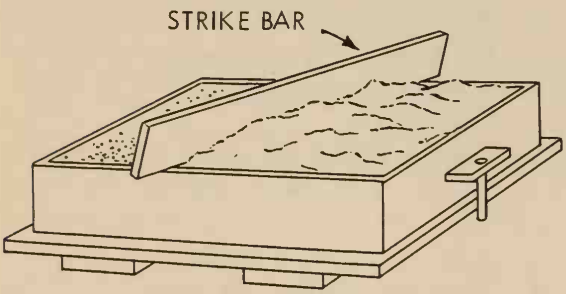


Fig. 8-7. Striking off excess sand with the strike bar.

7. Holding the mold board, drag, and bottom board firmly, carefully roll the drag over. The pins are now pointing up, the bottom board is at the bottom and the molding board is on top.
8. Remove the molding board. The flat side of the pattern is now visible. Check the surface of the sand and smooth with the slick, spoon, trowel, and lifter if necessary, Fig. 8-8. Also be sure the sand is packed around the edges of the pattern. Carefully blow off any extra particles of sand.
9. Dust some parting compound over the pattern, and sand to keep the two halves from sticking together. Set the cope part of the flask on the drag, Fig. 8-9. Insert the sprue pin and riser pin. The sprue pin is a tapered wooden or metal pin that is used to make a hole in the cope through which the metal is poured into the mold. The riser which has no taper, is used to make a hole for the metal to rise in and make up for some of the shrinkage when the metal cools.

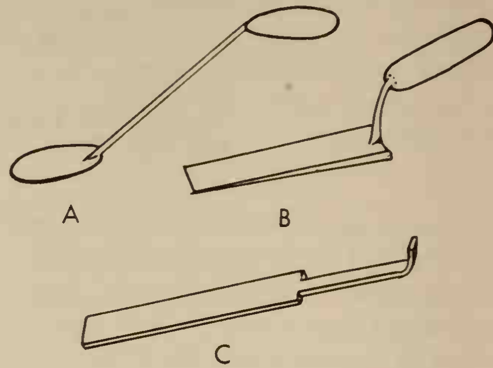


Fig. 8-8. Molders tools. (A) Slick and spoon; (B) Trowel; (C) Lifter.

10. Riddle sand into the cope, and ram as in Steps 3, 4, 5, and 6.
11. Vent the mold over the pattern so air, steam, and gas can escape as the molten metal is poured into the mold. This will help prevent the mold from exploding and keep blow

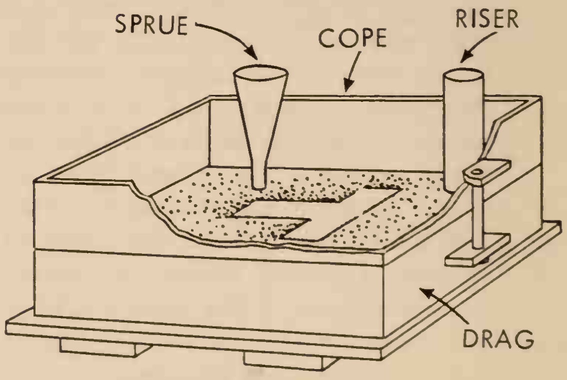


Fig. 8-9. Cope set on drag with riser pin and sprue pin in place.

holes (holes made by bubbles) from forming in the casting. A 1/16 in. welding rod slightly pointed on one end makes an excellent vent rod. Do not damage the pattern. A safe method is to push the vent rod into the mold slowly until it touches the pattern, and then pull it back about 1/4 in. Grip the vent rod at this level with your fingers. Punch several holes in the mold over the pattern, being careful to stop when the tips of your fingers touch the sand.

12. Remove the sprue pin, and the riser pin. Shape the top of the sprue hole like a funnel, with your fingers. Be sure there is no loose sand around the sprue and riser holes.
13. Lift the cope section of the flask off and lay it on its edge. Carefully moisten the sand around the pattern with a camel's hair brush or wet bulb.

    This makes the sand around the pattern firmer, and keeps the mold from breaking when the pattern is removed.
14. Place a draw pin in the pattern. If the pattern is metal the draw pin has threads on one end that are screwed into a taped hole in the pattern. A sharp pointed spike or a large wood screw may be used as a draw pin to remove a wood pattern. Rap the draw pin on all sides until the pattern is completely loose in the sand. Carefully and with a steady pull, lift the pattern straight up from the mold. If there is a little breaking off of the sand, repair it with a molder's tool.
15. Cut a small gate (channel) in the sand of the drag from the cavity made by the pattern to the place where the sprue is located. The width and depth of the gate will vary according to the size of the casting. The larger the casting, the larger the gate. For small plaques or book-ends, the gate should be about 1/2 in. deep and 1 in. wide. A piece of sheet metal 3 in. square, bent into a U-shape, makes an excellent gate cutter. Cut away a little sand at a time until the gate is completed. Now cut a gate between the riser and the cavity. Patch up any small breaks that have occurred in the mold. Blow off all loose sand with the bellows. <u>It is extremely important that all particles of loose sand are removed from the gates and cavity.</u> Small particles of sand in the mold will cause the casting to have pinholes.
16. Carefully replace the cope section on the drag. Check to be sure the mold is completely closed. Place a flask weight on top of the mold to keep the molten metal from lifting up the sand. Set the mold on the floor. It is now ready to receive the melted metal.

SAMMY SAFETY Says:

"Do not get the sand too wet. Water is on enemy of molten metal."

To make a mold with a split pattern, follow the same steps as described above except that half of the pattern is rammed up first in the drag. After the molding board is removed the other half of the pattern is put in place on the half in the drag. The cope section of the flask is put in place and the steps described are followed. When molding a split pattern, the largest half of the pattern should be rammed up in the drag.

MELTING FURNACE

There are several kinds of furnaces for melting metal. Commercial foundries use cupola furnaces to melt large amounts of metal. In a school shop where only a small amount of casting is done a small melting furnace is used such as shown in Fig. 8-10.

This furnace will melt aluminum, brass, and other light metals. Lead, tin, and some alloys can be melted in a large soldering furnace, forge, or with a gas welding torch. However, a melting furnace and

Fig. 8-10. Melting furnace. (Johnson Gas Appliance Co.)

a crucible is the safest and best method. The crucible can be used as the pouring ladle. Lifting tongs are used to pick up the crucible and place it in the crucible shank for pouring. Fig. 8-11, gives the melting points of common metals.

Metal	Degrees Fahrenheit
Solder (50/50)	400
Pewter	420
Tin	449
Lead	621
Zinc	787
Aluminum	1218
Brass	1700
Silver	1761
Copper	1981

Fig. 8-11. Melting points of metals.

POURING THE METAL

1. Select a crucible which is large enough to hold enough metal to fill the cavity, sprues, and risers. Fill the crucible with the pieces of metal to be melted.
2. Place the crucible in the furnace. Light the furnace and heat until the metal reaches the pouring temperature. Do not overheat. Overheated metal will produce defective castings.
3. Turn the furnace off. First turn off the air, then the gas. Add flux (commercial fluxes are used for aluminum, brass, and other alloys) to purify the metal. Stir the metal to bring the impurities to the top. Skim off the impurities (called slag).
4. Remove the crucible from the furnace with the crucible tongs, and place it in the crucible shank. Pick up the crucible shank so you are in a comfortable position. Stand to one side of the mold and pour the metal as quickly as possible into the mold in a steady stream. It must be poured rapidly enough to keep the gate and sprue full until the mold is filled.
5. After the metal has cooled, shake out the mold and remove the casting. The casting may still be hot so handle it with tongs.

SAMMY SAFETY
Says:

"Dress properly when working with molten metal. Wear a pair of clear goggles, leggings, and asbestos gloves.

Never stand or look over the mold during the pouring or immediately after the pouring because the molten metal might spurt out of the mold.

Do not light the furnace until you have your teacher's permission. If cold metal must be added to melted metal, be sure it is perfectly dry, and that tongs used are also perfectly dry, or an explosion will result."

QUIZ - UNIT 8

1. List four jobs in commercial foundry work and describe each one.
2. List the principal methods of casting metal.

3. Name five kinds of wood used for patternmaking.
4. What is meant by "draft?"
5. Give two reasons why pattern must be larger than finished casting.
6. What is the purpose of a core?
7. What is the purpose of "core prints?"
8. What is a flask?
9. What is the difference between the drag and the cope?
10. How is molding sand tempered?
11. Describe the purpose of the riser and the sprue.
12. What is the purpose of the gate?
13. Why is parting compound dusted on the pattern?
14. How should you be dressed when pouring molten metal?
15. Why is water an enemy of molten metal?

MACHINE SHOP

UNIT 9

1. Using measuring tools to take accurate measurements.
2. Machining metal on the lathe.
3. Information about the metal shaper and milling machine.

The machine shop plays an important role in the field of industry. Machine tools cut and shape metal more rapidly and more accurately than can be done by hand. The progress of industrial manufacturing and mass production depend upon machine tools. A skillful craftsman in metalwork should acquire an understanding of machine shop processes, and particularly the ability to work with accuracy and close tolerances.

There are many opportunities in the machining occupations for the bright and ambitious person. A skilled machinist is always in demand. There are thousands of craftsmen employed in skilled and semi-skilled machining occupations which include machine tool operators, all-round machinists, tool and diemakers, set up men, and layout men. The tool and diemaker is a highly skilled craftsman in the metalworking field. He must be able to operate machine tools and use precision measuring instruments. Other requirements include a knowledge of mathematics, blueprint reading, and machine operations.

MEASURING TOOLS

Measuring carefully and accurately is essential to good machine work. As a beginning machine shop student, you will want to learn to take accurate measurements with some of the basic devices used by the machinist. Some information on measuring tools was given in Unit 4. In this Unit we will discuss Inside and Outside Calipers, and the Micrometer.

OUTSIDE CALIPER

This tool is used to take external measurements of cylindrical stock. To set an outside caliper, hold the instrument in the right hand and a scale in the left hand, Fig. 9-1. One leg of the caliper is supported against the end of the scale with a

finger. Adjust the other leg until it splits the line on the scale which represents the correct measurement. To take a measurement, hold the caliper at right angles to the center line of the work and push it

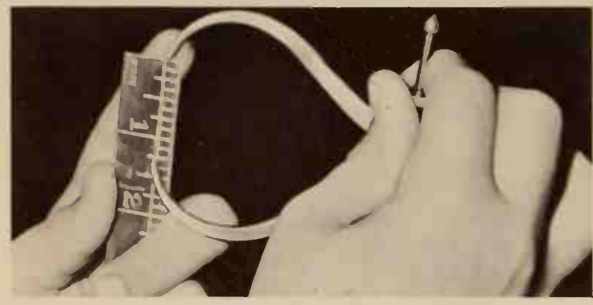


Fig. 9-1. Setting an outside caliper.

gently back and forth across the diameter of the cylinder to be measured, Fig. 9-2. The caliper is properly adjusted when it will slip over the piece with a very slight drag. Do not force the caliper over the work since this will spring the legs and the measurement will not be accurate.

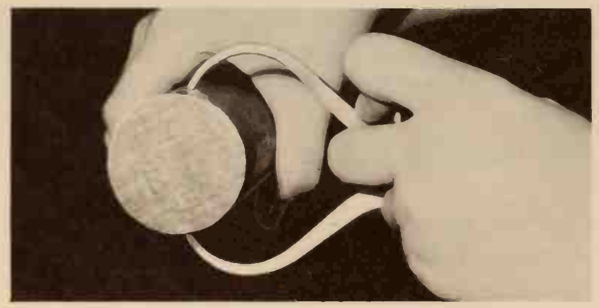


Fig. 9-2. Taking a measurement with an outside caliper.

INSIDE CALIPER

An inside caliper is used to gauge inside diameters. To set an inside caliper for a desired dimension, hold a scale square on a flat surface. Then rest one leg of the tool on this surface at the edge and end of the scale. Adjust the other leg until it centers the proper graduation on the scale, Fig. 9-3. To take a measurement with an inside caliper, place it in the hole as indicated in Fig. 9-4. Adjust

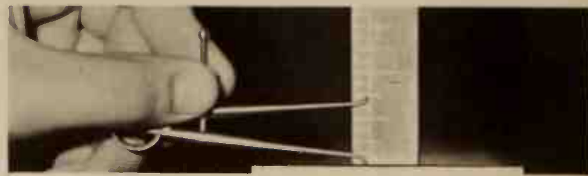


Fig. 9-3. Setting an inside caliper.

the caliper until it will slip into the hole with a very slight drag. To transfer measurements from an inside caliper to an outside caliper or vice versa, rest the point of one leg of the inside caliper on the point of an outside caliper, Fig. 9-5. Pivot the top point of the inside caliper in

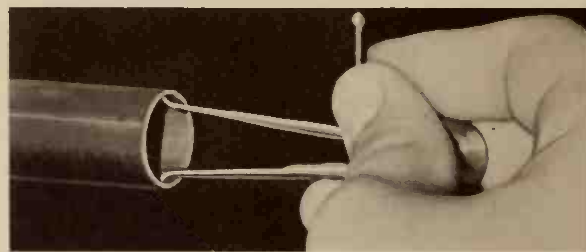


Fig. 9-4. Taking a measurement with an inside caliper.

and out of the top point of the outside caliper. Adjust the thumb screw until the leg drags slightly as it contacts the leg of the outside caliper.

MICROMETER

A micrometer is a precision measuring tool which is used by the machinist. He calls it a "mike." Micrometers are made in different sizes and styles. The outside mike which will be described in this unit resembles a C clamp, Fig. 9-6. It has 40

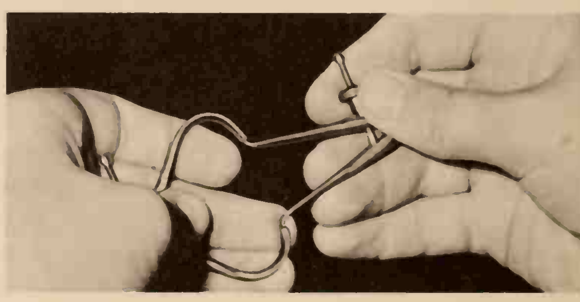


Fig. 9-5. Transferring measurements.

threads per inch on the screw. One complete turn of the thimble moves the spindle 1/40 in. or 0.025 in. The thimble is marked off in 25 equal parts, each of which is 1/1000 in. or 0.001. On the sleeve there are 40 lines to the inch. Every four divisions on the sleeve are marked 1, 2, 3, etc., which represents 0.100, 0.200, 0.300 in., etc.

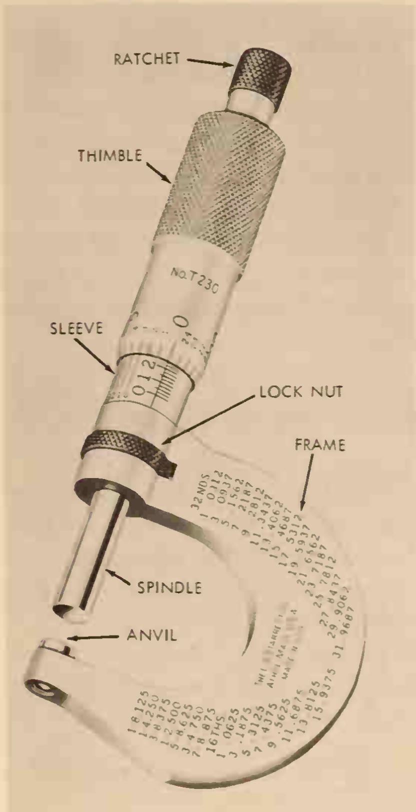


Fig. 9-6. Parts of a micrometer. (The L. S. Starrett Co.)

READING THE MICROMETER

1. Turn the thimble until the spindle is closed against the anvil. The reading should be zero with the 0 mark on the thimble directly over the 0 mark on the sleeve.
2. Back off the thimble slowly. As each mark on the thimble passes the horizontal line on the sleeve the micrometer has been opened 0.001 in. When the thimble has been backed off one complete turn, 25 of these marks have passed the horizontal line on the sleeve and the micrometer has been opened 0.025 in.
3. To read the micrometer, first take the reading on the sleeve and then add to it the reading on the thimble. For example in Fig. 9-7, you can see two divisions past the 1 on the sleeve, or six full divisions. The thimble reading is 5. Your reading would be 0.155 in. (0.025 in. x 6 = 0.150 in. + .005 in. = 0.155 in.) Look at the micrometer settings in Fig. 9-8, and see if you can read them.

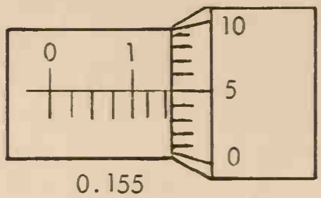


Fig. 9-7. One hundred fifty-five thousandths of an inch (0.155).

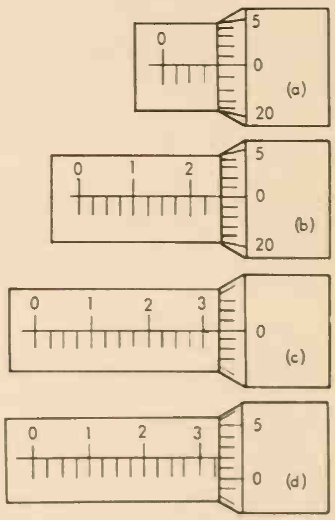


Fig. 9-8. "Mike" readings. (A) One hundred thousandths of an inch (0.100); (B) Two hundred fifty thousandths of an inch (0.250); (C) Three hundred twenty-five thousandths of an inch (0.325); (D) Three hundred twenty-seven thousandths of an inch (0.327).

After you learn to read the mike, practice using it by measuring some pieces

of stock. When using the mike, hold it in the right hand and screw the thimble down until it lightly touches the stock, Fig. 9-9. Be careful not to screw it down too tight. Take the reading. Back the spindle off the stock and remove the mike and put it in a safe, clean place. Do not mike a piece of metal while it is turning in the lathe. Never tap a micrometer against other objects or drop it, since this may destroy its accuracy.

Fig. 9-9. Taking a measurement with a micrometer.

THE METAL LATHE

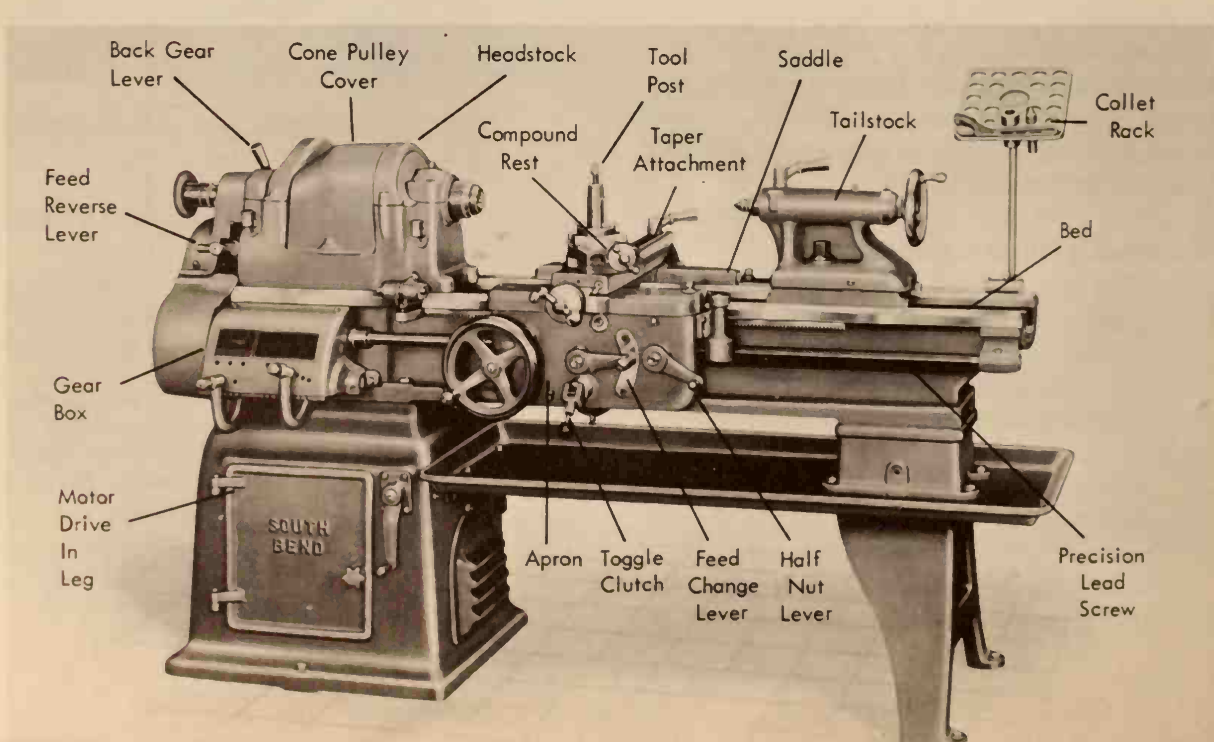
A metal lathe is used to cut and shape metal by revolving the piece against a cutting tool which is clamped on a movable carriage mounted on the lathe bed. They are used to perform many processes, including turning down metal rods, facing, cutting off, turning tapered sections, cutting threads, drilling, and boring.

The principal parts of the lathe include the headstock, tailstock, bed, carriage, and the feeding and threading mechanisms, Fig. 9-10. After you become familiar with the names and location of the various parts of the lathe, get permission from your teacher to move the different handles and levers by hand, with the power off, to see what they do. All parts should move easily, never force them.

TURNING BETWEEN CENTERS

1. Carefully locate the center on both ends of the stock to be turned. The center of round stock may be located using the centerhead of the combination set, Fig. 9-11. Rectangular and square pieces are easily centered by drawing diagonal lines, Fig. 9-12.

Fig. 9-10. Principal parts of a metal lathe. (South Bend Lathe)



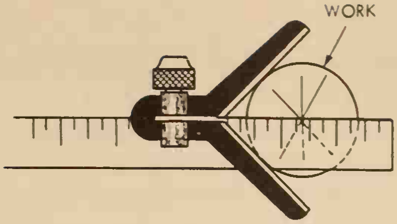


Fig. 9-11. Locating the center of round stock.

2. Center punch the center point on each end of the stock.
3. Check the alignment of the lathe centers, Fig. 9-13. The live center should run true. Carefully bring the dead center to within 1/16 in. of the live center. If the points of the two

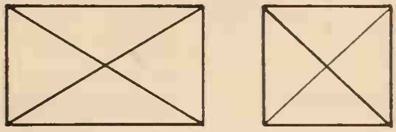


Fig. 9-12. Locating the center of square and rectangular stock.

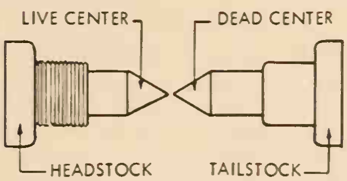


Fig. 9-13. Checking alignment of lathe centers, looking from above.

centers are not in line, move the tailstock over by adjusting the set-over screws, Fig. 9-14.

4. Remove live center and replace it with a drill chuck, Fig. 9-15. Fasten

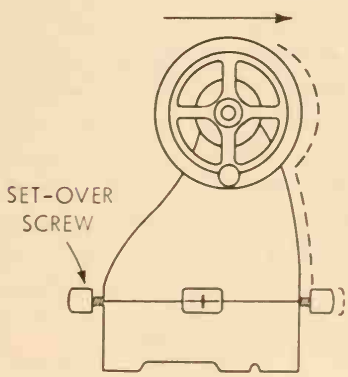


Fig. 9-14. Setting tailstock.

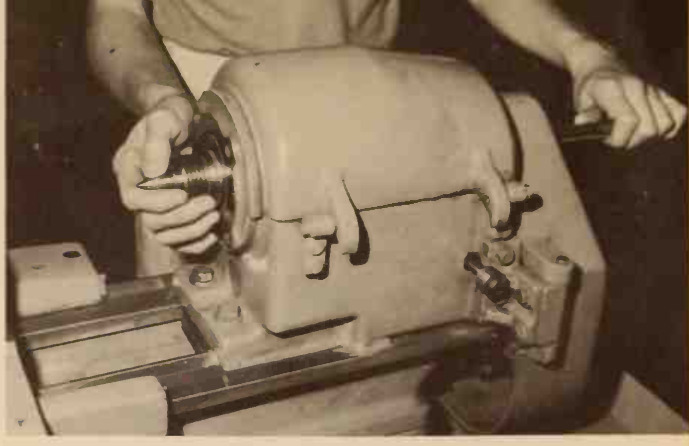


Fig. 9-15. Remove live center from headstock with a knockout rod. Hold the center so it will not fall and damage the point.

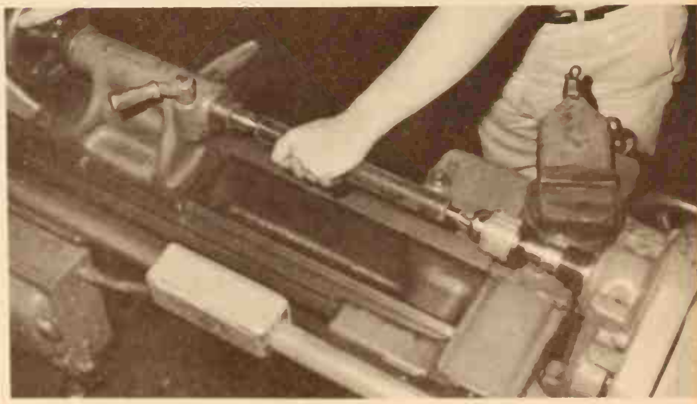
a combination drill and countersink in the chuck, Fig. 9-16.

5. Move the tailstock to such a position that the work just fits between the point of the drill and the dead center, and clamp the tailstock in place.

Fig. 9-16. A combination drill and countersink. (Cleveland Twist Drill Co.)

6. Put the center-punch mark of one end of the stock on the drill point. Holding the work piece steady, turn the tailstock wheel to bring the dead center into the other center-punch mark carefully, Fig. 9-17.
7. Apply lard oil or cutting compound to the drill when drilling steel. Cast

Fig. 9-17. Center drilling on the lathe.



iron should be drilled dry.

8. Hold the work with the left hand and start the lathe and feed by turning the tailstock spindle handwheel slowly until the center hole is drilled to the correct size, Fig. 9-18. Reverse the work in the lathe and drill the other end.
9. Remove the drill chuck and screw

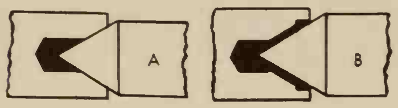


Fig. 9-18. Center drilled holes. (A) Properly drilled; (B) Drilled too deep.

a faceplate on the headstock spindle. Clean and oil the threads of the headstock spindle and faceplate. Place a board across the ways of the lathe and screw the faceplate onto the spindle until it is tight against the shoulder. Never bring the faceplate against the spindle shoulder with a bang since this will make it difficult to remove.

10. Clean out the spindle hole with a rag and insert the live center.
11. Clamp the smallest size lathe dog that will fit on one end of the work piece.
12. Place a small amount of white lead lubricant in the center hole at the

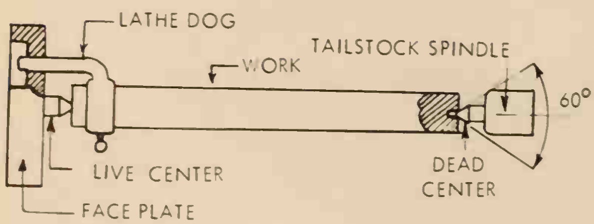


Fig. 9-19. Work mounted between centers.

tailstock end. Insert the work between the centers and screw up the tail center just snug enough to prevent the lathe dog from chattering when machine is in operation, Fig. 9-19.

13. Choose the proper lathe tool cutter bit for the job, Fig. 9-20.
14. Insert the tool holder in the tool post. Insert the cutter bit in the tool

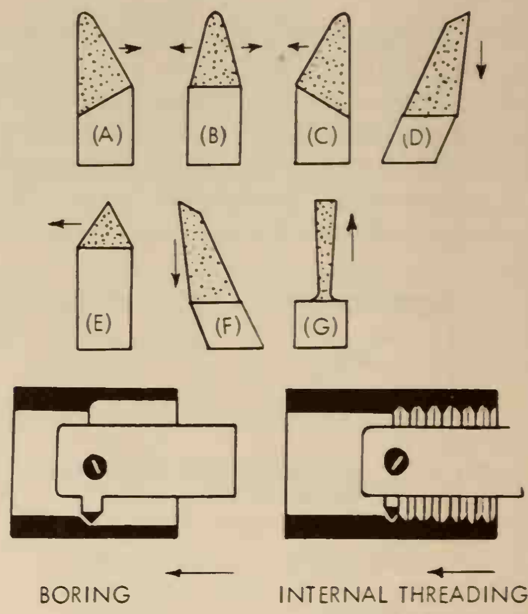


Fig. 9-20. Common lathe cutting tools. (A) Left-hand turning tool; (B) Round-nose turning tool; (C) Right-hand turning tool; (D) Left-hand facing tool; (E) Threading tool; (F) Right-hand facing tool; (G) Parting or cut-off tool.

holder and tighten. Adjust the cutter bit and tool holder so the cutting edge of the tool is at the height of the lathe centers or a little above as shown in Fig. 9-21.

15. Adjust the lathe for the proper speed and feed. The cutting speed varies

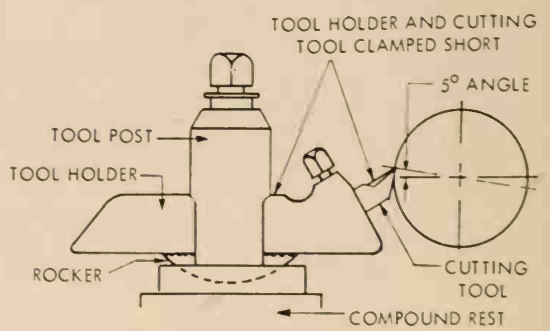


Fig. 9-21. Tool holder and cutting tool properly adjusted.

for different metals and for different sizes of stock. Feed is the distance the carriage, carrying the cutting tool, travels along the bed with each revolution of the spindle. Fig. 9-22 gives the cutting speed and feed for some of the more common metals.

Dia. in In.	Cast Iron 75 f.p.m.	Machine Steel 100 f.p.m.	Soft Brass 200 f.p.m.	Aluminum 300 f.p.m.
1	287	382	764	1146
2	143	191	382	573
3	95	127	254	381
4	72	95	190	285
5	57	76	152	228
6	48	64	128	192
7	41	55	110	165
8	36	48	96	144
9	32	42	84	126
10	29	38	76	114

Fig. 9-22. Spindle speeds in revolutions per minute for average cuts with high-speed steel cutter bits.

16. The cut should be from the tailstock toward the headstock so the pressure is on the live center which turns with the work. Start the lathe and screw the cutter bit into the stock to take a cut. Engage the power fed and make the cut.
17. Check to see if the live and dead centers are in alignment as follows: after a complete cut has been made on the diameter and length of the stock, measure both ends with a micrometer. If the measurement is the same at both ends the centers are aligned. If the measurements are different adjust the tailstock set-over screws and take another cut. Repeat these operations until both ends measure the same.
18. Adjust an outside caliper to 1/32 in. over the finished size. Turn on the lathe and turn the cross-feed handle to move the cutter bit into the work for a roughing cut that will true up the stock. Make a trial cut about 1/4 inch wide.
19. Turn the power off and check the trial cut with the calipers. Two or more roughing cuts may have to be taken.
20. Turn on the power and cut a little past the halfway point on the length of the stock. Continue cutting until the stock has been cut to within 1/32 in. of finished diameter. Remove the lathe dog and place it on the other end of the stock. Place the stock in the lathe and cut the other end to within 1/32 in. of the finished size.
21. Place a finishing cutter bit in the tool holder and make a trial cut about 1/4 in. long. Do not change cross-feed setting. Mike the cut. If the diameter for example, is .004 in. oversize, turn the cross-feed micrometer collar .002 in. in and take another trial cut. Check the diameter again with the mike. If the diameter is correct, continue the longitudinal cut to a little past the center.
22. Do not change the cross-feed setting. Remove the lathe dog. Place a band of aluminum or copper about 1/2 in. wide around the other end of the stock to protect the finished surface from the lathe dog screw. Slip the lathe dog over the soft metal band and clamp it in place.
23. Cut the other half of the stock to the finished size. When turning work to two or more diameters, cut the largest diameter first. Mark the stock at the first shoulder and cut this diameter. Continue this procedure until the smallest diameter has been turned.

FILING AND POLISHING

Tool marks can be removed and a smooth, bright finish can be obtained on the surface of a piece by filing and polish-

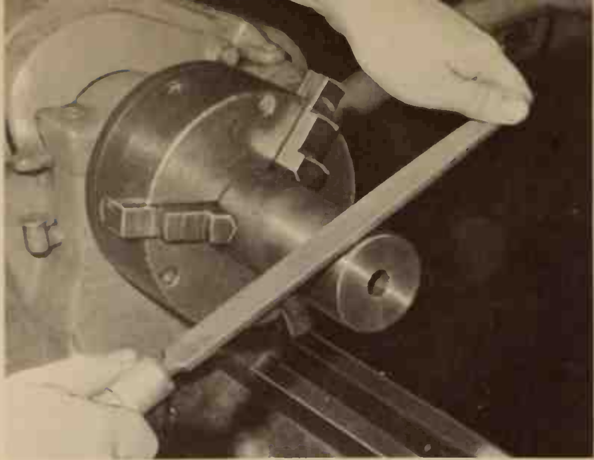


Fig. 9-23. Filing in the lathe. Keep the left arm well above the revolving chuck.

ing, Fig. 9-23. Use a fine mill file or a long-angle lathe file, Fig. 9-24. Adjust the lathe so that the work will make two or three revolutions for each stroke of the file. Take long, even strokes across the metal. File just enough to obtain a smooth surface. Always keep your file clean and free from chips with a file card.

A very smooth, brightly polished finish can be obtained by using fine grades of abrasive cloth after filing. Apply oil on the emery cloth and adjust the lathe to run at high speed. Keep the abrasive cloth moving slowly from one end to the other.

SAMMY SAFETY *Says:*

"Keep your sleeves rolled up and hold your left elbow high so it will not be hit by the revolving lathe dog. Be careful not to let the emery cloth wrap around the revolving work."

TURNING A TAPER

Short tapers, such as those on a lathe center or center punch can be turned by

Fig. 9-24. A long-angle lathe file. (Nicholson File Co.)

clamping stock in a lathe chuck and setting the compound rest to the desired degree of taper. The point of the cutter bit is set on center and the carriage is locked in place. Make the cut by turning the compound rest feed screw, Fig. 9-25.

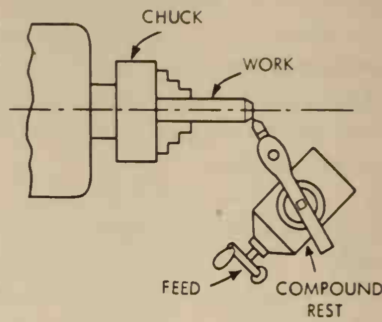


Fig. 9-25. Using the compound rest to cut a taper.

Long tapers are turned by setting the tailstock, Fig. 9-26, over or by means of a taper attachment. To find the amount of tailstock set-over for a taper, use this formula:

$$\text{Set-over} = \frac{\text{total length}}{\text{length to be tapered}} \times \frac{\text{large diameter minus small diameter}}{2}$$

When the taper per foot is known use this formula:

$$\text{Set-over} = \frac{\text{taper per foot, in inches}}{2} \times \frac{\text{length of piece}}{12}$$

LATHE CHUCKS

Lathe chucks are used to hold work that cannot be mounted between lathe centers. There are many machining operations which can be performed on work held in a chuck, such as turning, threading (internal

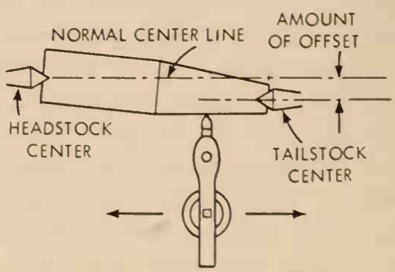


Fig. 9-26. Tailstock off-set to cut a taper.

and external), boring (straight and taper), reaming, and cutting off stock.

There are several types of chucks used for machining, the most popular being the 4-jaw independent chuck and the 3-jaw universal chuck, Fig. 9-27. The 4-jaw independent has four reversible jaws which can be independently adjusted. It will hold round, square and irregular shapes. The work can be adjusted to practically any degree of accuracy required. The 3-jaw universal chuck will hold round and hexagonal stock. The jaws move in or out together and automatically center the work within about three thousandths of an inch. This chuck is usually provided with one

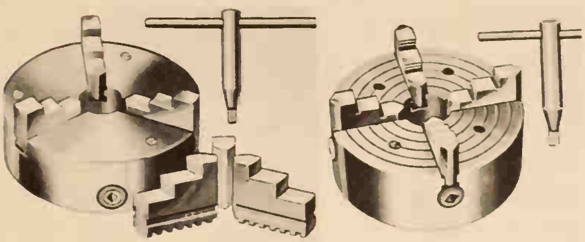


Fig. 9-27. Lathe chucks. Left, 3-jaw universal chuck. Right, 4-jaw independent chuck. (South Bend Lathe)

set of jaws for outside chucking, and another set for inside chucking. The jaws cannot be reversed. The 3-jaw universal chuck is not used where extreme accuracy is required.

USING LATHE CHUCKS

When mounting a chuck on the lathe spindle, thoroughly clean and oil the threads of the spindle and the chuck back. A very small chip or burr will prevent the chuck from running smoothly. Remove the live center by holding the center with your right hand and giving the center a sharp tap with the knock out bar through the spindle hole. Place a piece of wood across the ways of the lathe to protect them. Grip the chuck by placing your fingers in the center between the jaws, and lift it onto the piece of wood. Turn the headstock spindle with the left hand and guide the chuck onto the thread. Be sure to get the chuck started square on the threads. The chuck should screw on easily. Continue to screw the chuck onto the spindle by hand until it is tight against the shoulder. Never bring the chuck against the spindle shoulder with a bang since this will make it difficult to remove.

To remove a chuck from the lathe spindle, engage the back gears and place a wood block between a chuck jaw and the back ways of the bed. Turn the spindle pulley by hand to loosen the chuck. Then place a board across the ways under the chuck. Continue to screw the chuck off by hand.

To mount the work in a 4-jaw independent chuck, open the four jaws an equal distance from the center. Use the concentric rings on the face of the chuck as a guide. Insert the work and tighten the jaws until it is approximately centered and held firmly. The work is then centered more accurately by bringing a piece of chalk in contact with the work as the chuck is slowly rotated, Fig. 9-28. The jaw opposite

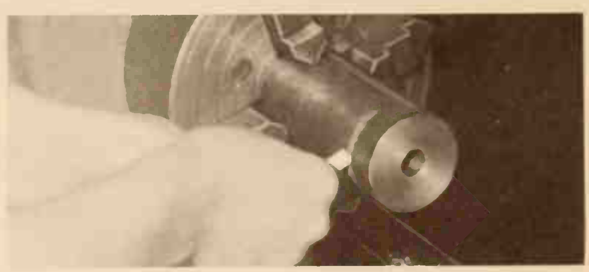


Fig. 9-28. Centering work by the chalk method.

the chalk mark is loosened slightly. Then tighten the jaw on the side where the chalk mark is located. Continue this procedure until the work is centered. Check all four jaws to be sure they are securely tightened before starting to machine the work.

To mount work in a 3-jaw universal chuck, open jaws until the work can be inserted. Then tighten jaws with chuck key. Be sure to remove the key.

Fig. 9-29. Facing in the lathe.

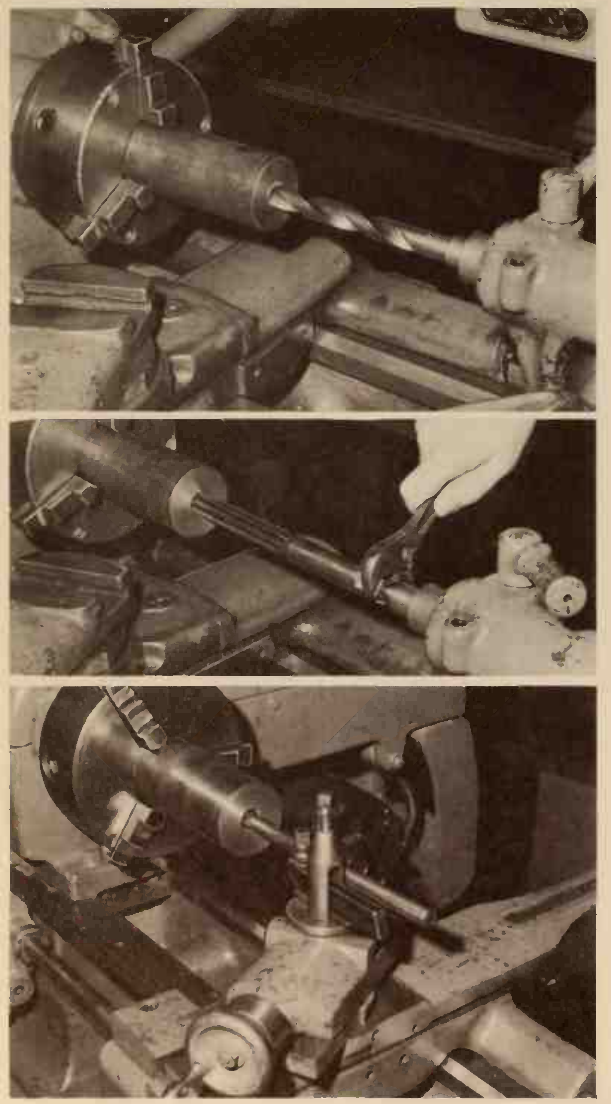


Fig. 9-30. Top, Drilling in the lathe with a taper-shank drill. The drill is held in a drill chuck if it is a straight-shank. Fig. 9-31. Center, Hand reaming in the lathe. Do not use power when hand reaming. Fig. 9-32. Bottom, Boring in the lathe with a boring bar.

FACING

The term Facing refers to the cutting or squaring of the end of a piece of work, as in Fig. 9-29. The cutting tool is set so the cutting edge passes through the center of the work. Roughing cuts are made from the outside of the work toward the center. Finishing cuts are made from the center to the outside. Lock the carriage in place when making facing cuts.

DRILLING

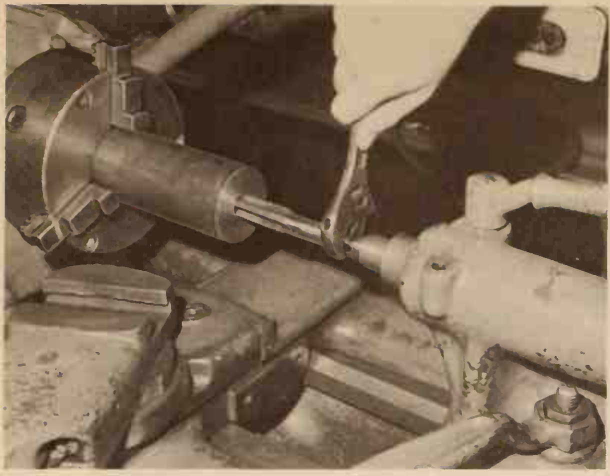
Drilling on the lathe is done by holding the work in the lathe chuck and securing the drill in the tailstock, Fig. 9-30. After the work has been faced, spot the center for the drill with the cutter bit. Adjust the lathe to the correct speed for drilling. Select a drill 1/64 in. undersize to allow for reaming. Insert the drill in the tailstock. Drills with straight shanks are chucked in a drill chuck that has a tapered shank which will fit the taper in the tailstock. Bring the tailstock close to the work, so the tailstock spindle will not have to be run out any farther than necessary to drill the hole. After the hole has been drilled, hand ream it in the lathe, Fig. 9-31. If a large hole is to be drilled, it is good practice to drill a pilot hole first.

BORING

Boring is done when the hole to be cut is not standard size, or to cut a very accurate hole. Use a boring tool holder with a bar which can be adjusted, so the cutting edge of the tool is in the proper position for cutting, Fig. 9-32.

THREADING

A lathe may be used to cut a great variety of threads. This is done by using a specially sharpened tool bit. The power feed is adjusted to move the carriage along at a rate that will cause the tool to cut the required number of threads per



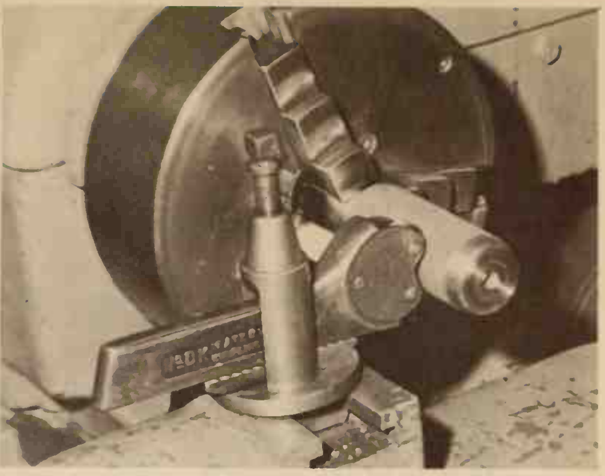


Fig. 9-33. Left, Tapping in the lathe. Fig. 9-34. Using lathe for knurling.

inch. This is a very fascinating operation. Ask your teacher for a demonstration.

An easy method for cutting internal threads, although not as accurate, is to use a tap in a lathe. Place the center hole of the tap on the point of the dead center and the work end of the tap in the (tap) drilled hole of the work, Fig. 9-33. Adjust the tailstock so there is just enough pressure to hold the tap in place. Turn the tap with a cresent wrench. After each turn of the tap it will be necessary to readjust the tailstock center. It is not necessary to complete the job in the lathe. After the threads have been started straight with the taper tap, the threading can be completed at the bench with the plug and bottoming tap.

KNURLING

Knurling is a process of embossing the surface of the work, Fig. 9-34. Some pieces of work and handles of tools are knurled to provide a better gripping surface. Knurling tools are available which will produce fine, medium, coarse, straight, and diamond patterns.

The knurling tool is clamped in the tool post at right angles to the work. Adjust the lathe for the slowest back geared speed. Mark off the space to be knurled. Start the lathe and force the knurling tool into the work at the right end. The knurls should be pressed hard into the work at the start and then the pressure is relieved a little after making sure they track. Use plenty of oil to lubricate the knurling wheels regardless of the kind of material being knurled. Then engage the longitudinal feed of the carriage and let the knurling tool feed across the work to the left. To make a deeper cut reverse the lathe spindle and let the knurling tool feed back to the starting point. Do not remove the knurl from the impression. Force the tool deeper into the work, and let it feed back across the work. Repeat this procedure until the knurling is finished.

THE SHAPER

The shaper is a machine tool which has the cutting tool mounted in a ram, Fig. 9-35. The ram moves back and forth horizontally across the work. This machine can be used for shaping horizontal, vertical, angular and curved surfaces, Fig. 9-36. The work is either mounted in the vise, or clamped to the table. The table can be moved vertically or horizontally. The shaper size is determined by the maximum stroke in inches, such as 7 in., 12 in., 16 in., and 24 in. Except for some of the tool angles, the shaper cutting tools are the same as those used in the lathe. Since the shaper cuts on the forward stroke only, the side-relief angle needs to be only about 3 or 4 degrees. The end-relief angle, or front clearance, should be approximately 3 or 4 degrees.

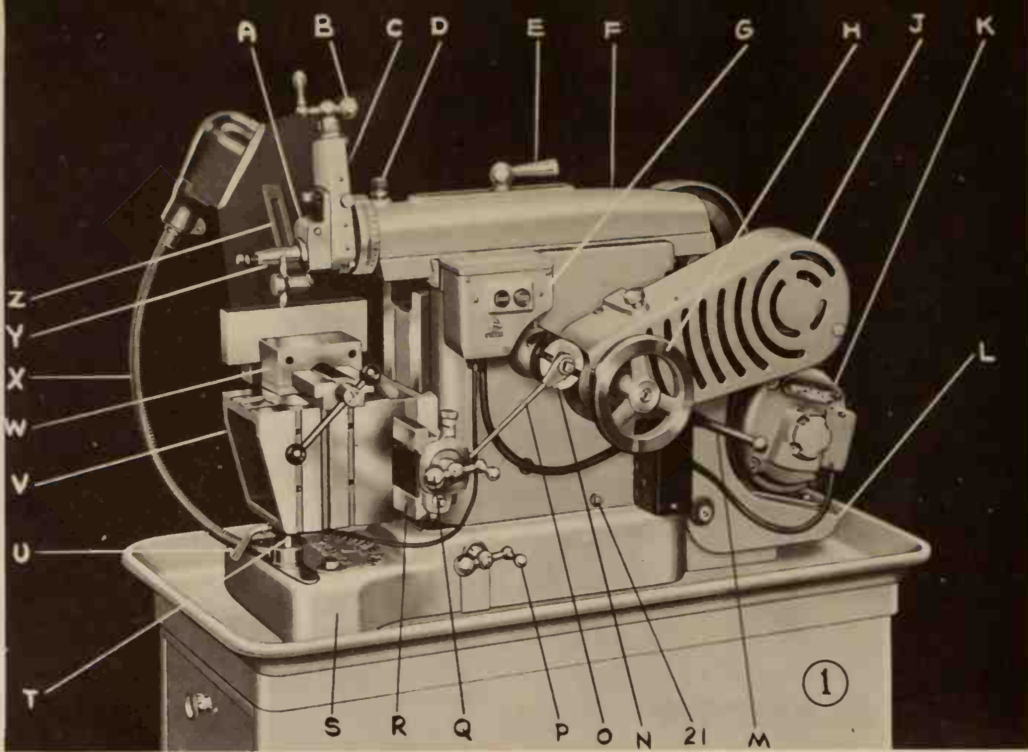


Fig. 9-35. Principal parts of a shaper: (A) Clapper box, (B) Down-feed handle, (C) Head, (D) Headswivel lock screw, (E) Ram clamping handle, (F) Ram, (G) Switch box, (H) Hand wheel, (J) Drive-pulley guard, (K) Motor, (L) Motor cradle, (M) Tension release lever, (N) Eccentric, (O) Feed rod, (P) Table elevating crank, (Q) Cross feed crank, (R) Cross-rail, (S) Base, (T) Work-table support, (U) Support locking handle, (V) Work table, (W) Vise, (X) Lamp, (Y) Tool post, (Z) Tool holder. (South Bend Lathe)

THE MILLING MACHINE

The milling machine produces one or more machined surfaces on the work. The work is clamped to the table of the machine, or held in a fixture or jig which is clamped to the table. A rotating cutter shapes and smoothes the metal. There are several types of milling machines. The two most commonly found in the school

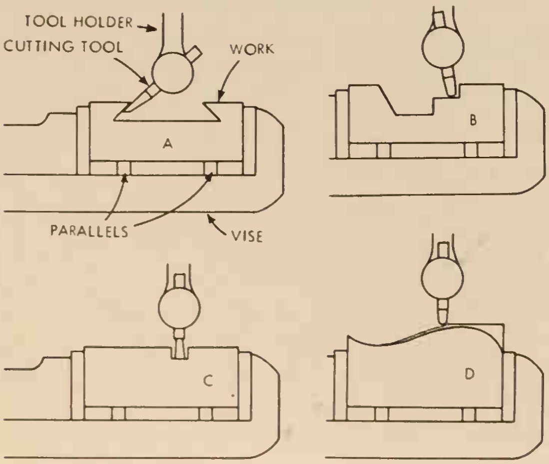


Fig. 9-36. Cuts that can be made on a shaper: (A) Angular cuts; (B) Horizontal; Vertical, and Angular cuts; (C) Slotting cut; (D) Simple form cutting.

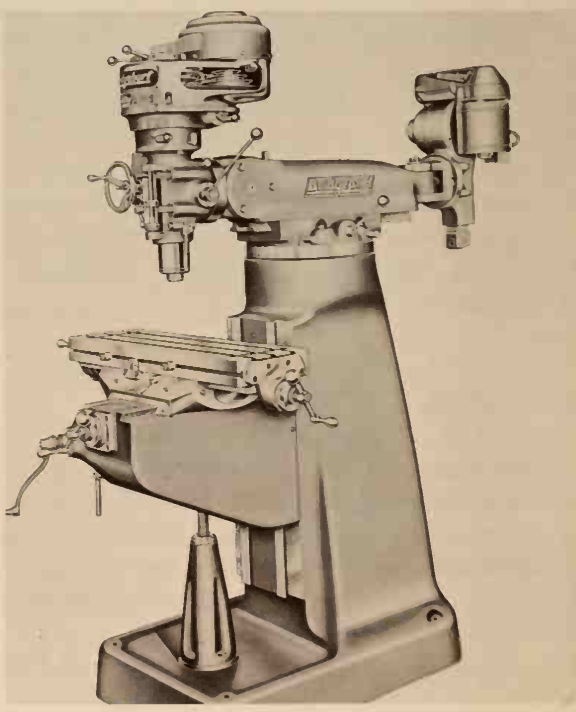


Fig. 9-37. Vertical milling machine. (Bridgeport Machines, Inc.)

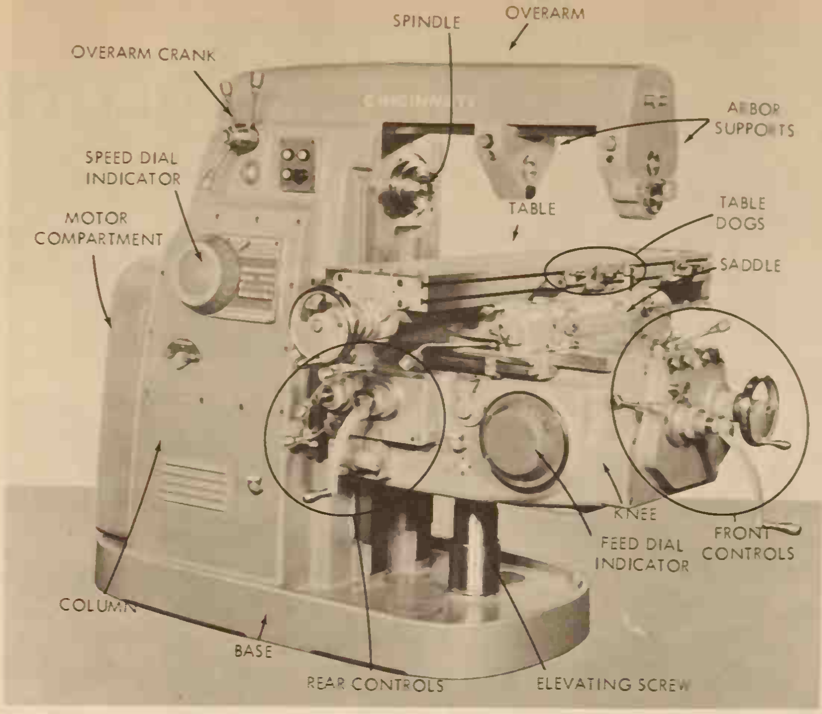


Fig. 9-38. Horizontal milling machine. (Cincinnati Milling Machine Co.)

shop are the Vertical Milling Machine, Fig. 9-37, and the Plain Horizontal Milling Machine, Fig. 9-38. These machines are known as knee-and-column type because the spindle is fixed in the column. The table (which is a part of the knee) can be adjusted longitudinally, transversely and vertically. Milling machines can be used to cut straight or irregular surfaces slots, and grooves. They can also be used to cut gear teeth. Some milling operations are shown in Fig. 9-39, and Fig. 9-40.

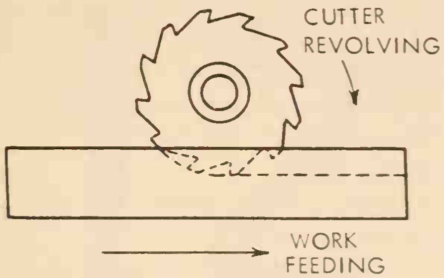


Fig. 9-39. Milling a slot in a block of metal.

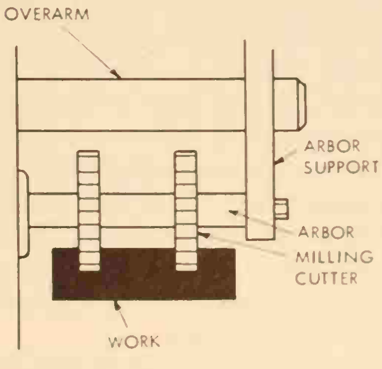


Fig. 9-40. Gang milling---cutting two slots in a block of metal.

QUIZ - UNIT 9

1. The tool and diemaker must have a knowledge about ---, ---, and ---.
2. An outside caliper is used to take ---, ---.
3. An inside caliper is used to take --- ---.
4. If the reading on the micrometer sleeve is two divisions past the one and the thimble reading is 15, the reading would be ---.
5. What is an engine lathe?
6. A combination drill and countersink is used to --- --- for --- --- turning.
7. For very accurate turning you should use the --- --- chuck.
8. Name two ways to turn tapers in a lathe.
9. List five operations that can be performed in a lathe.
10. Describe the use of a shaper.
11. What is the difference between a vertical mill and a horizontal mill?

METALWORKING PROJECTS

UNIT 10

The projects covered in this Unit are examples of what can be constructed to assist you in your study of the various units of metal work. Your instructor may also have other projects which you will want to consider. You can also get ideas for additional projects by visiting gift shops and department stores and from magazines and catalogues.

The projects illustrated in this Unit have been selected to provide easy ones for the beginning metalworking student to construct. Others which are more difficult to make have also been included to present a challenge to the student and to give him experience in problem solving as he develops more proficiency in the metals area. These projects lend themselves to many different designs and construction methods. You may want to change the size of some of these plans to fit your own needs. For example, the shelf may be too large, or you might want to hang your house number sign on a post which will require a different bracket.

HOUSE NUMBER SIGN

This house number sign, Fig. 10-1, is a good beginning project. Its construction involves some important hand tool operations which can be applied to numerous other projects. You may want to change the design of the scroll work or the shape of the plate which holds the numbers. Patterns for the numbers can be made so they can be cast in the foundry or they may be cut from aluminum or brass sheet stock.

MATERIAL:

Standard:	1 pc. band iron 1/8 x 1/2 x 37 in.
Scrolls:	1 pc. band iron 1/8 x 1/2 x 21 in.
Plate:	1 pc. black iron 22 ga. 5 x 14 in.
Hooks:	1 pc. mild steel 1/8 in. dia. x 7 in.
Rivets:	4 black iron 1/8 x 1/2 in. round head.
Numbers:	Aluminum or brass - cast in foundry, cut from sheet stock, or purchase.

PROCEDURE:

1. Draw a full-size pattern of the scroll on squared paper. See Fig. 10-2.
2. Figure the amount of material needed for the scrolls and cut to correct length.
3. Square the ends of the metal and remove burrs.
4. Form the scrolls.
5. Cut material to length for the standard.
6. Lay out pointed ends on both legs of the standard.
7. Cut the ends to shape and file the edges.
8. Mark off bends on material for standard.
9. Make 90-deg. bends with a small radius as shown on drawing.
10. Lay out number plate on 22 ga. black iron.
11. Cut number plate to size, and file all edges.
12. Lay out location of holes.
13. Center punch and drill holes.
14. Cut out stock for hooks.
15. Form hooks.
16. Locate rivet holes on scrolls and center punch.
17. Drill 1/8 in. dia. holes in scrolls.
18. Locate rivet holes on the standard and center punch.
19. Drill 1/8 in. dia. holes in the standard.
20. Rivet the scrolls to the standard.
21. Draw full-size pattern of figures on metal. (If you cast your figures in the foundry, skip procedure 21 and 22).
22. Cut out figures and polish.
23. Locate rivet holes on figures.
24. Center punch and drill holes in figures for rivets.
25. Rivet figures to both sides of the plate.
26. Paint as desired.
27. Insert hooks in the standard and attach the number plate.

Fig. 10-1. House number sign.

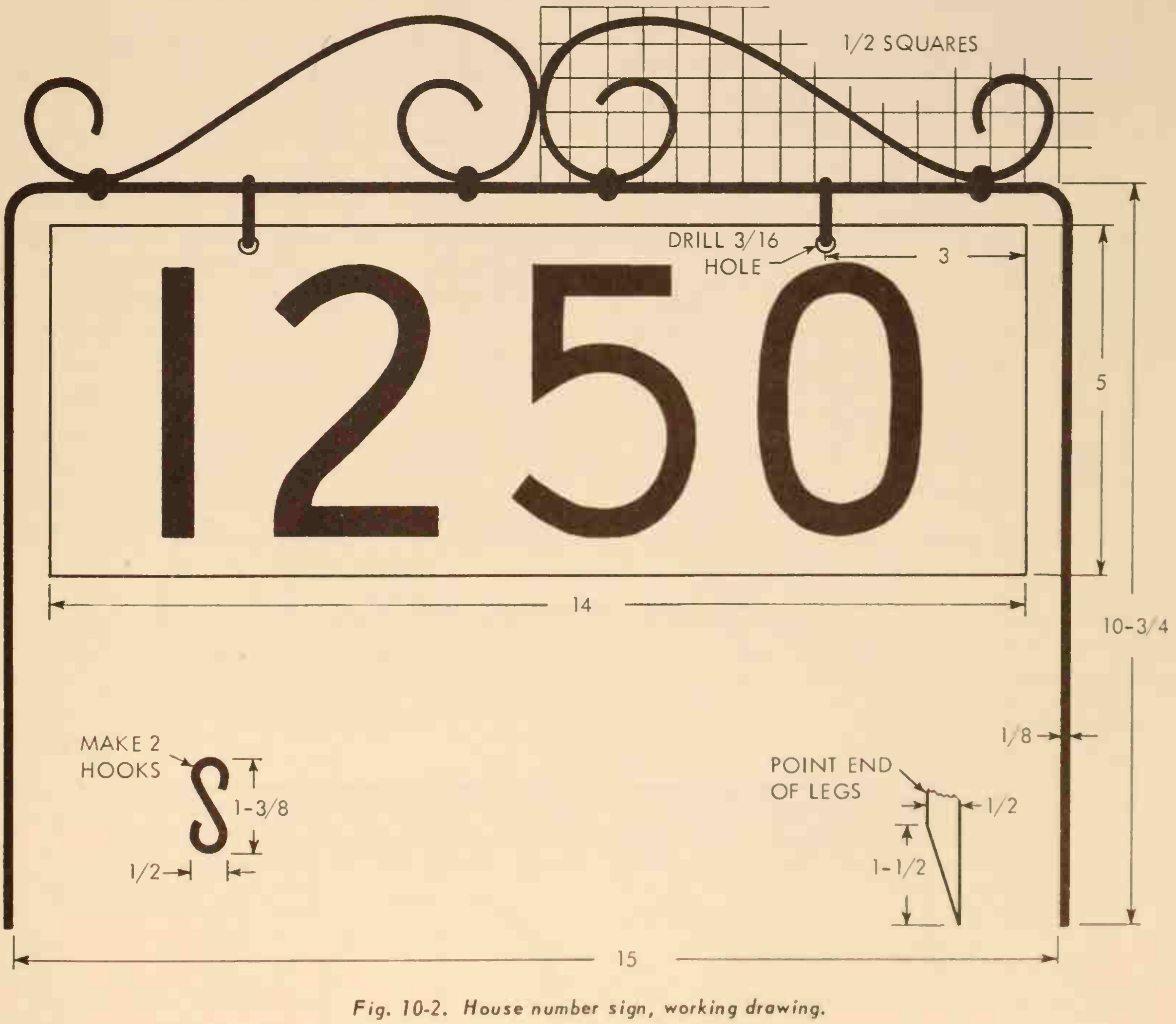


Fig. 10-2. House number sign, working drawing.

Fig. 10-3. Wall plant holder.

WALL PLANT HOLDER

This wall plant holder, Fig. 10-3, is an attractive planter for displaying trailing vines and green plants. Flattened expanded metal or perforated metal can be used for the back. All of the pieces are joined with solder. While soft solder, properly applied will serve satisfactorily, hard soldering will make the project stronger. If you have a spot welder in your shop, the expanded metal can be joined to the wire frame with it very easily. All of the metal parts must be cleaned thoroughly before applying the finish. This project is very attractive when given a satin black finish.

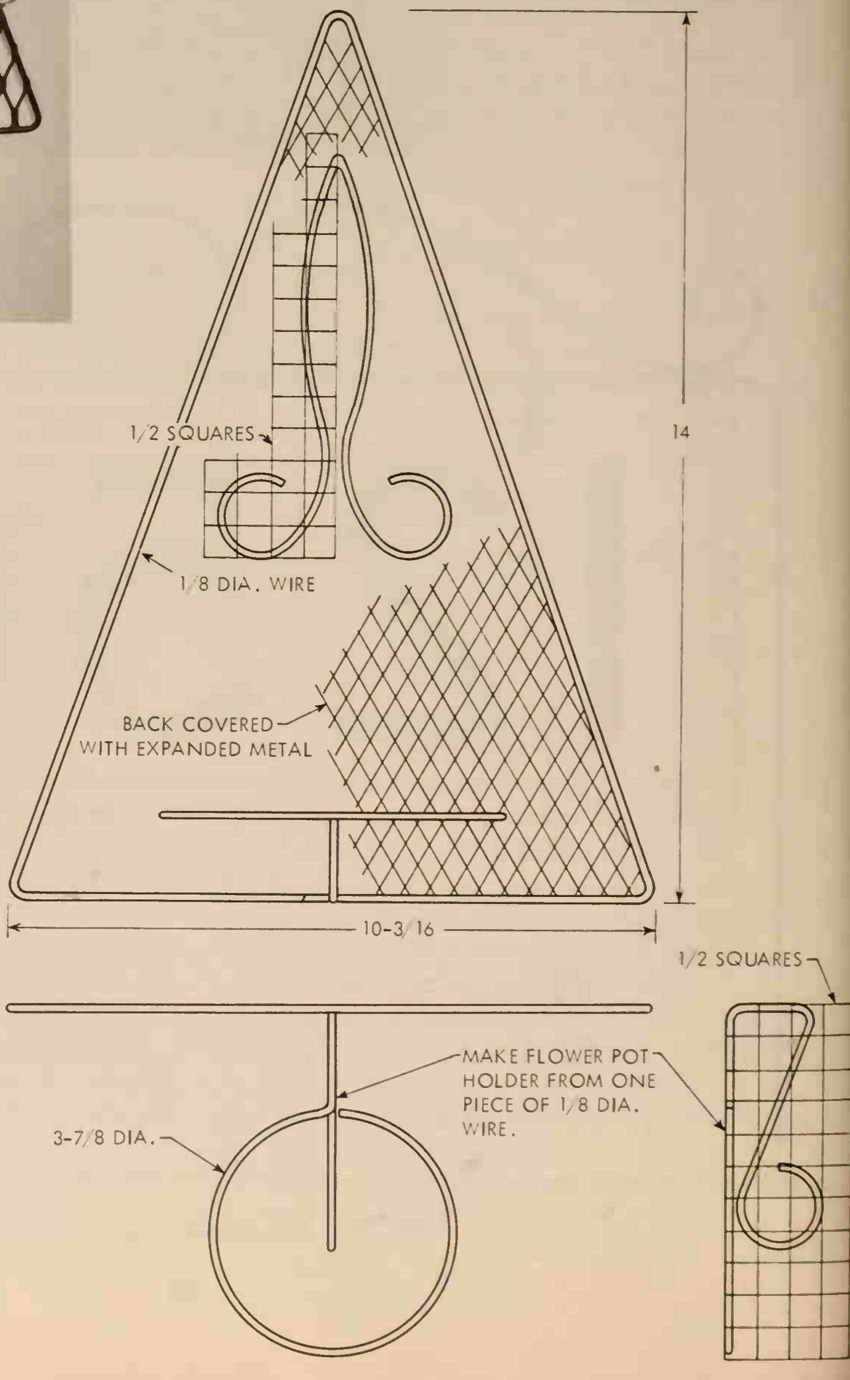


Fig. 10-4. Wall plant holder, working drawing.

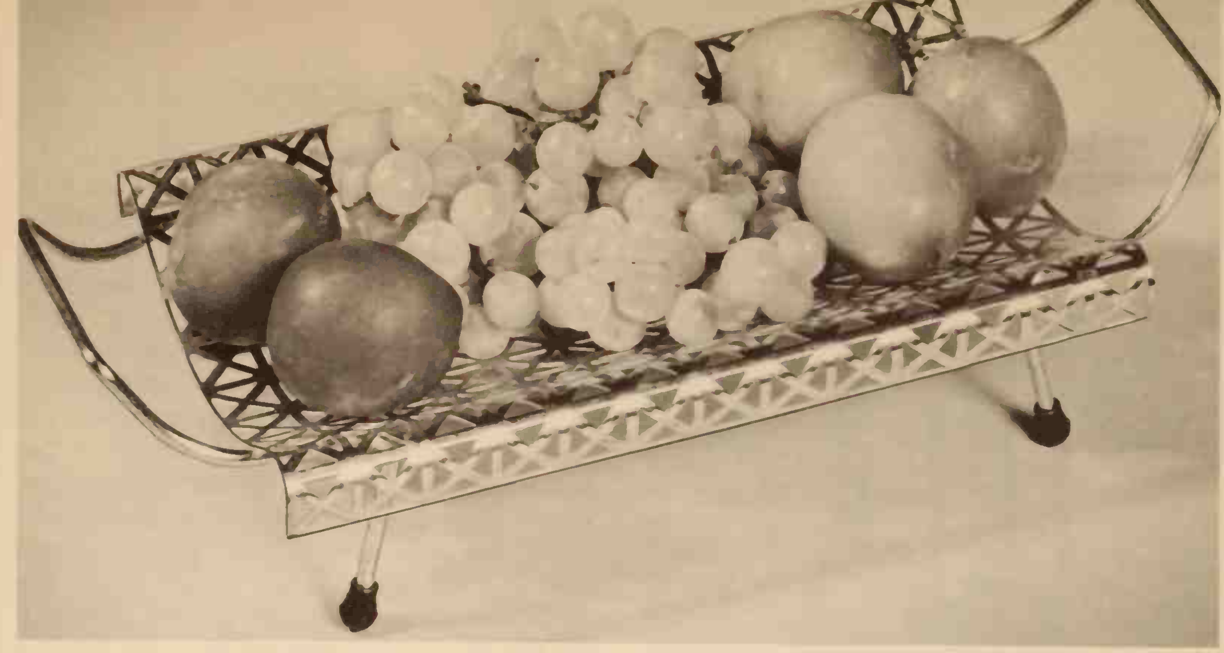


Fig. 10-5. Fruit tray.

FRUIT TRAY

The tray, Fig. 10-5, is a project which has many uses. It makes an attractive center piece when filled with fruit or flowers, or it can be used to serve buns. The size can be changed to meet your particular need. Perforated metal which has a pattern that can be cut out so there is a straight border around the edges works best for this project. It will be necessary for you to draw a full-size pattern, Fig. 10-6, of all the curved parts so you can check them as they are formed.

When all of the pieces for the project have been shaped, solder the legs and handles to the tray. Wire or clamp one side of the handle to the tray so the handle and legs will be held in place, and at the correct angle while being soldered. Remove the wire and solder the other side. A propane torch is a handy tool for this kind of soldering job. Wash the soldering flux off to the metal and dry all the parts. Polish and apply the finish selected.

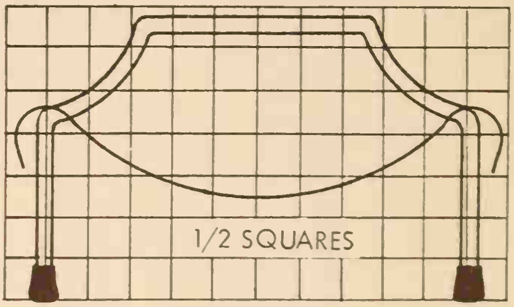


Fig. 10-6. Fruit tray, working drawings.

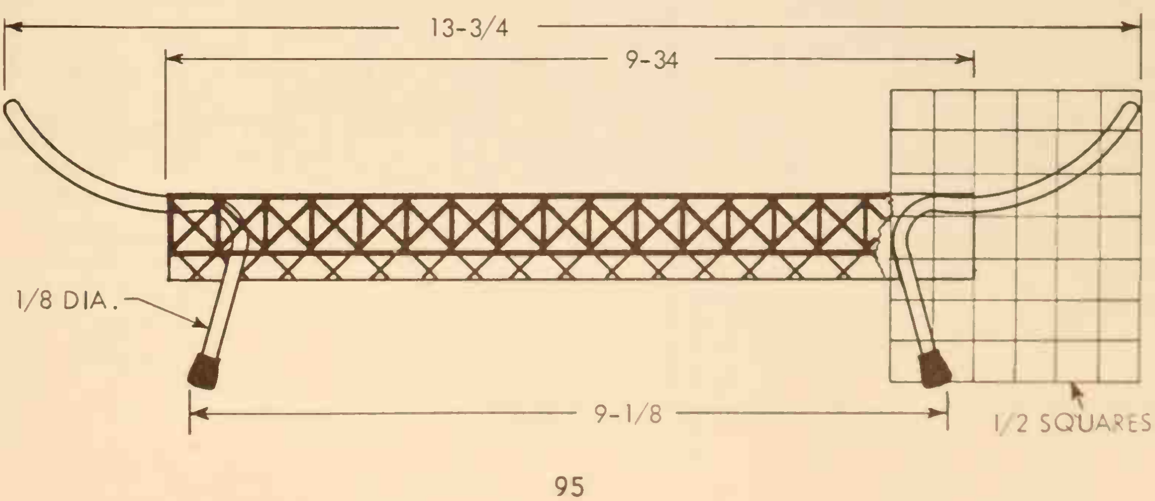
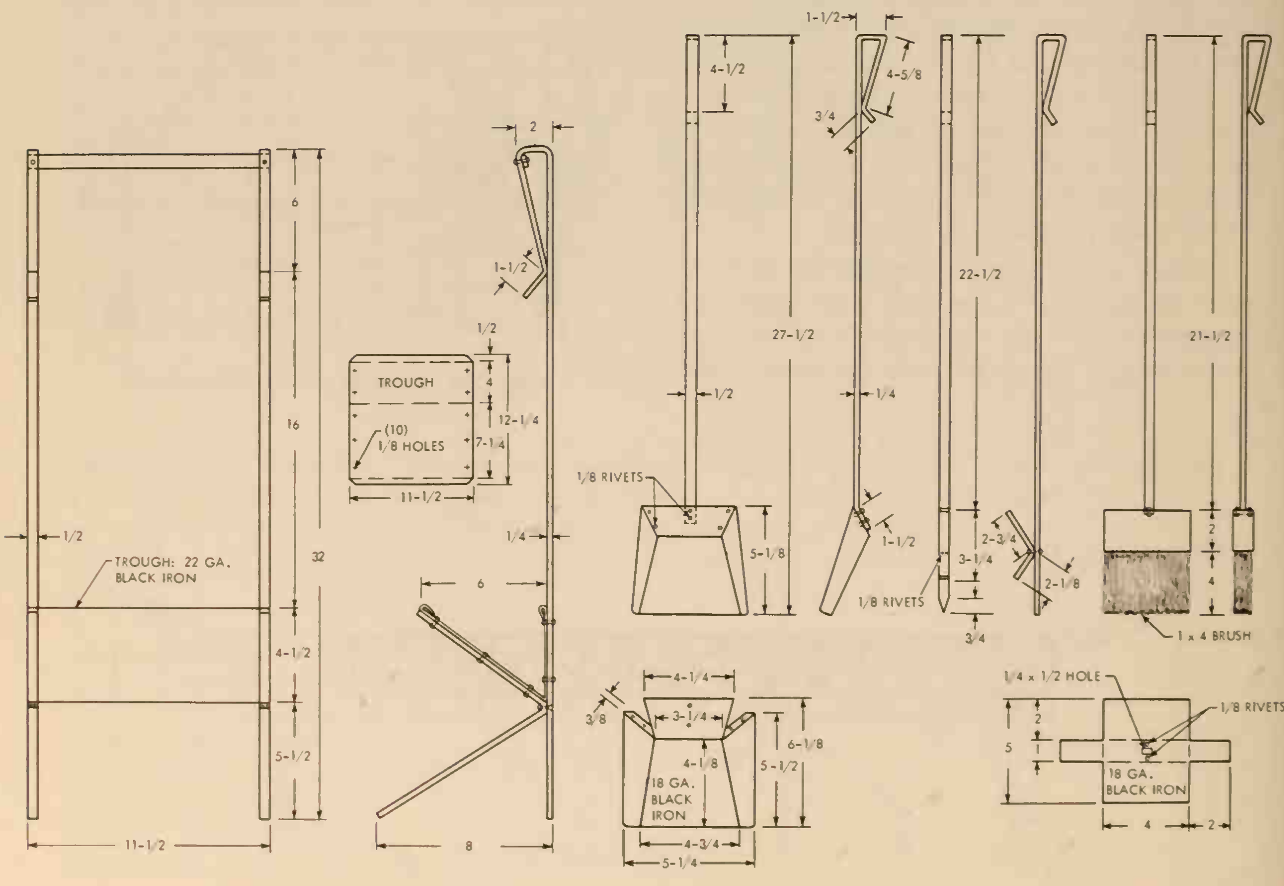


Fig. 10-7. Fireplace tools.

FIREPLACE TOOL SET

The fireplace set, Fig. 10-7, will enhance the beauty of any fireplace as well as being very useful. The holder and tools are easy to make and many bench metal operations are performed in the construction of this set. The drawing, Fig. 10-8, specifies rivets for fastening the various parts, however, if you have welding equipment available this set makes an excellent welding project. The handles of the tools can be peened or left plain. The brush can be purchased at most department and hardware stores. If you can not find one the exact size, either alter the dimensions of the brush holder shown in the drawing or cut the brush to fit. A satin black finish is practical for the set. Aluminum may be used in place of band iron if you prefer.

Fig. 10-8. Below, Fireplace working drawings.



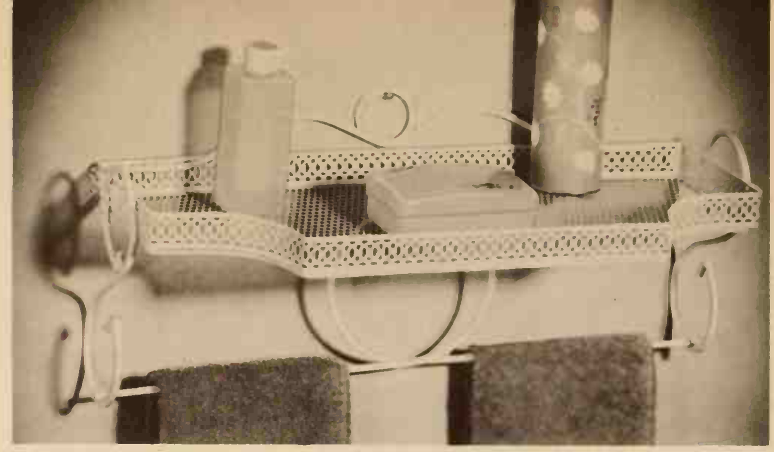


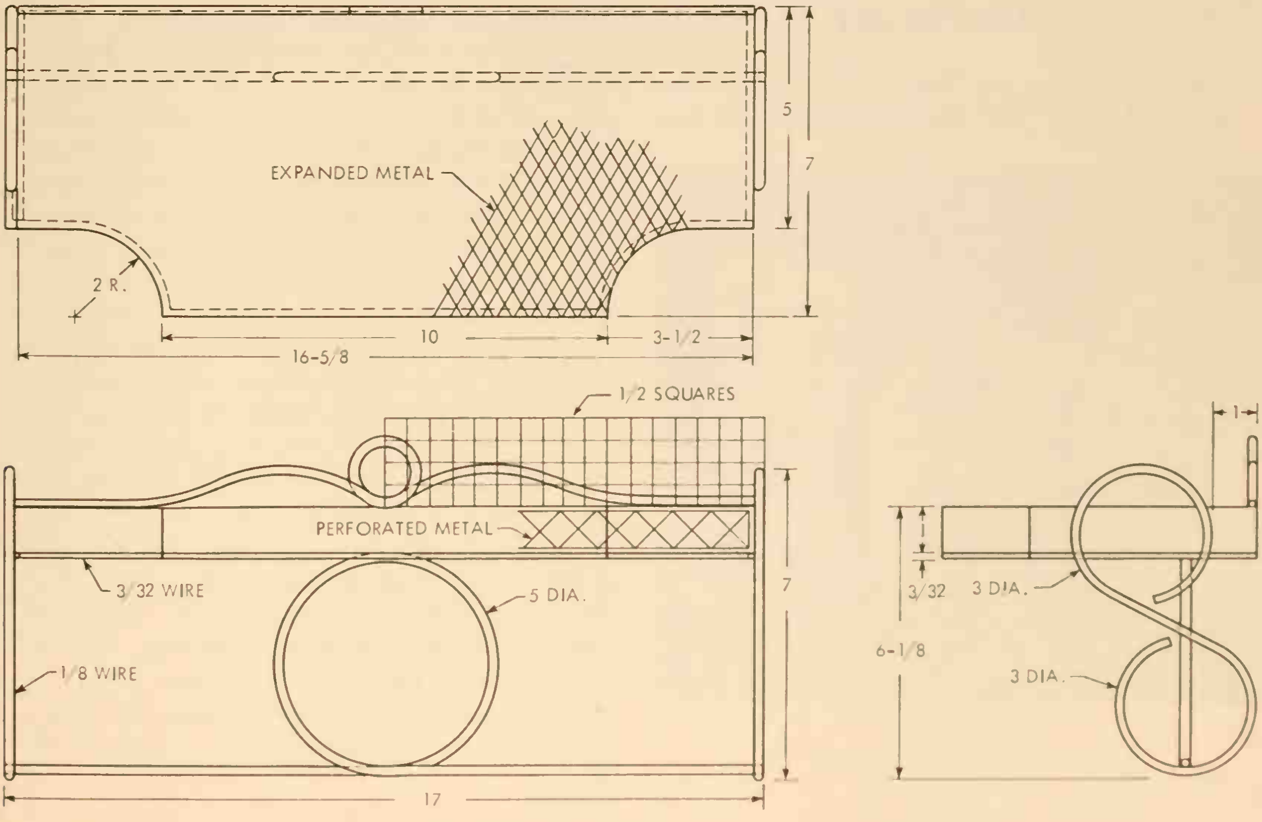
Fig. 10-9. Wall shelf.

SPACE SAVER SHELF

The space saver shelf, Fig. 10-9, will provide a place for cosmetics, perfumes, and towels in the bathroom, or spice jars, tea towels, etc. in the kitchen.

You should not attempt this project until you have made several other metal projects successfully. The parts must be accurately made so they will fit together properly and the shelf will hang evenly. The most difficult problem involved is the soldering or welding the parts in the correct position. This project might be used as a problem solving experience to develop jigs to form the various parts and clamping devices to hold them in place while soldering. A combination of expanded metal for the bottom of the shelf, and perforated metal for the sides, can be used to add variety to the design. If the project is enameled it should be sprayed on to obtain best results--be careful not to get runs. Two or three thin coats work better than one thick application.

Fig. 10-10. Wall shelf, working drawing.



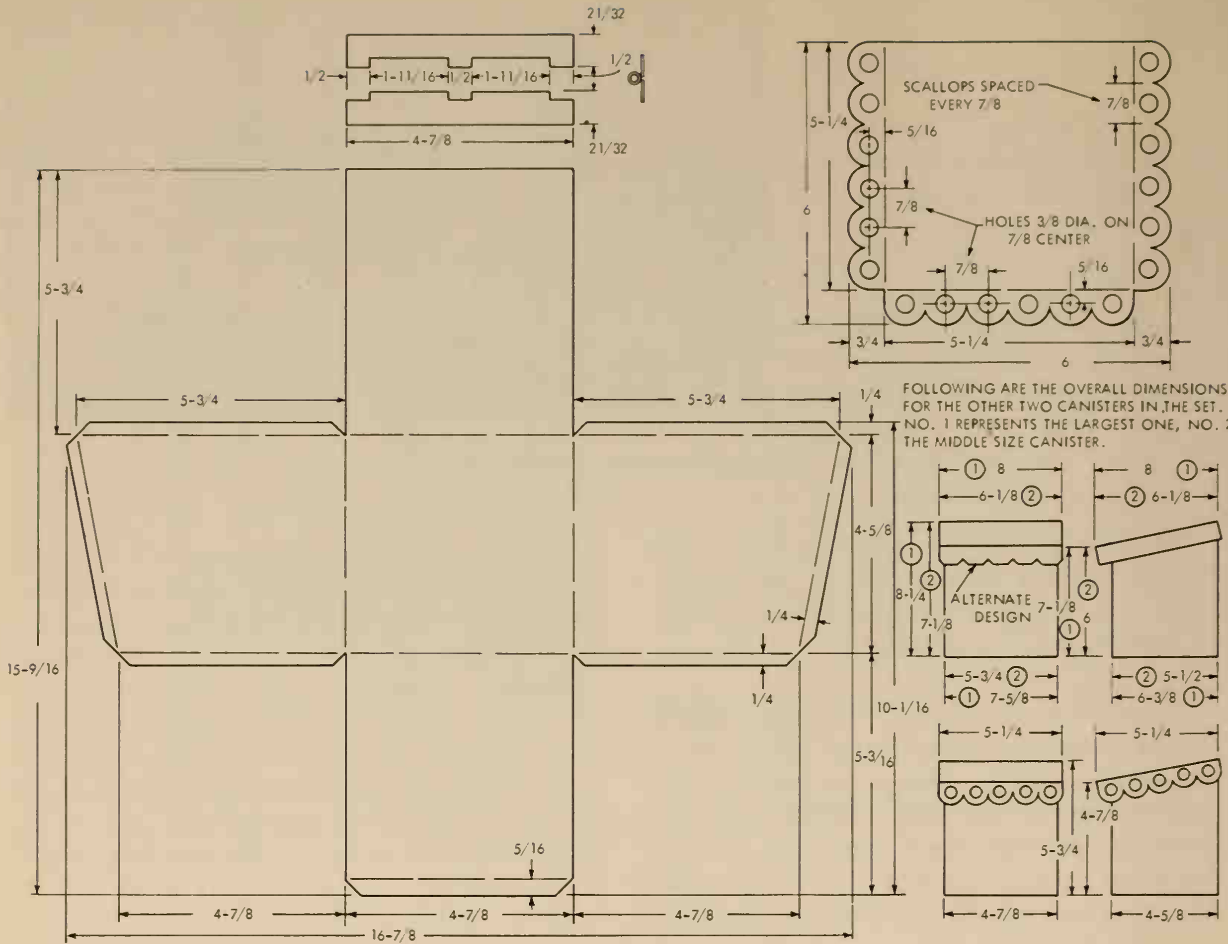


Fig. 10-12. Canister set, working drawing.

CANISTER SET

The canister set, Fig. 10-11, will make a decorative and useful addition to any kitchen. By changing the height or width the boxes can be designed for various uses. Use 26-ga. sheet metal, 24 oz. copper, or .032 in. aluminum for the body and lid. The hinge should be made from 28 ga. stock. This project is not too difficult to make but does require careful and accurate layout to obtain satisfactory results. Bending the box to shape must be carefully checked so the top edges of the four sides will match and not have one edge higher than the other. The hinge can be formed around the wire (No. 16) to be used as the pin to hold the two halves of the hinge together. Use a pair of pliers to bend the hinge tabs around the wire. A bar folder or turning machine can also be used to assist in this operation. Create your own design for the overhang on the lid. Join the box by soldering or riveting. Fasten the hinge to the body first, then join it to the lid. If aluminum or copper is used, give all the surfaces a satin or brushed finish.

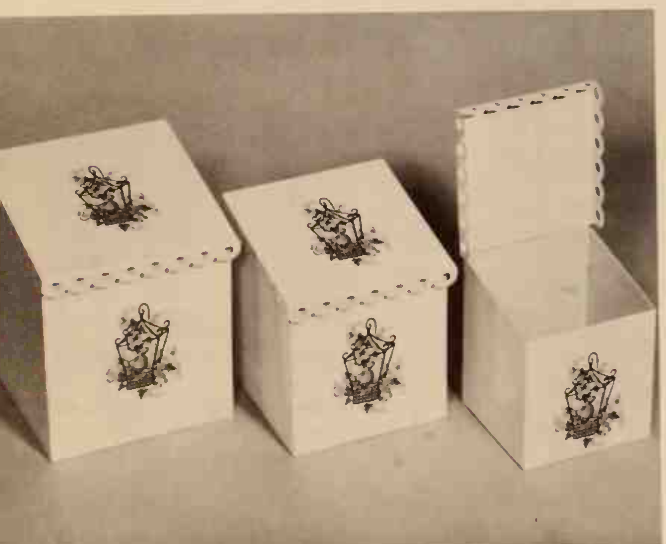


Fig. 10-11. Canister set

BIRD FEEDER

The bird feeder, Fig. 10-13, will provide you with many interesting hours watching birds that visit the feeder. The house can be made of 24 ga. sheet metal. The front of the roof has a wired edge--use No. 16 wire, Fig. 10-14. The perch is made of 1/2 O.D. aluminum tubing. Fasten the perch to the floor of the feeder with either round-head machine screws, or rivets. The roof and the floor of the feeder can be joined to the sides by soldering, riveting, or spot welding. The pipe which can be used to attach the feeder to a pole is optional and depends on how you plan to hang your bird feeder. The finish should be a dark shade of green or brown since birds tend to be cautious of bright colors.

Fig. 10-13. Bird feeder.

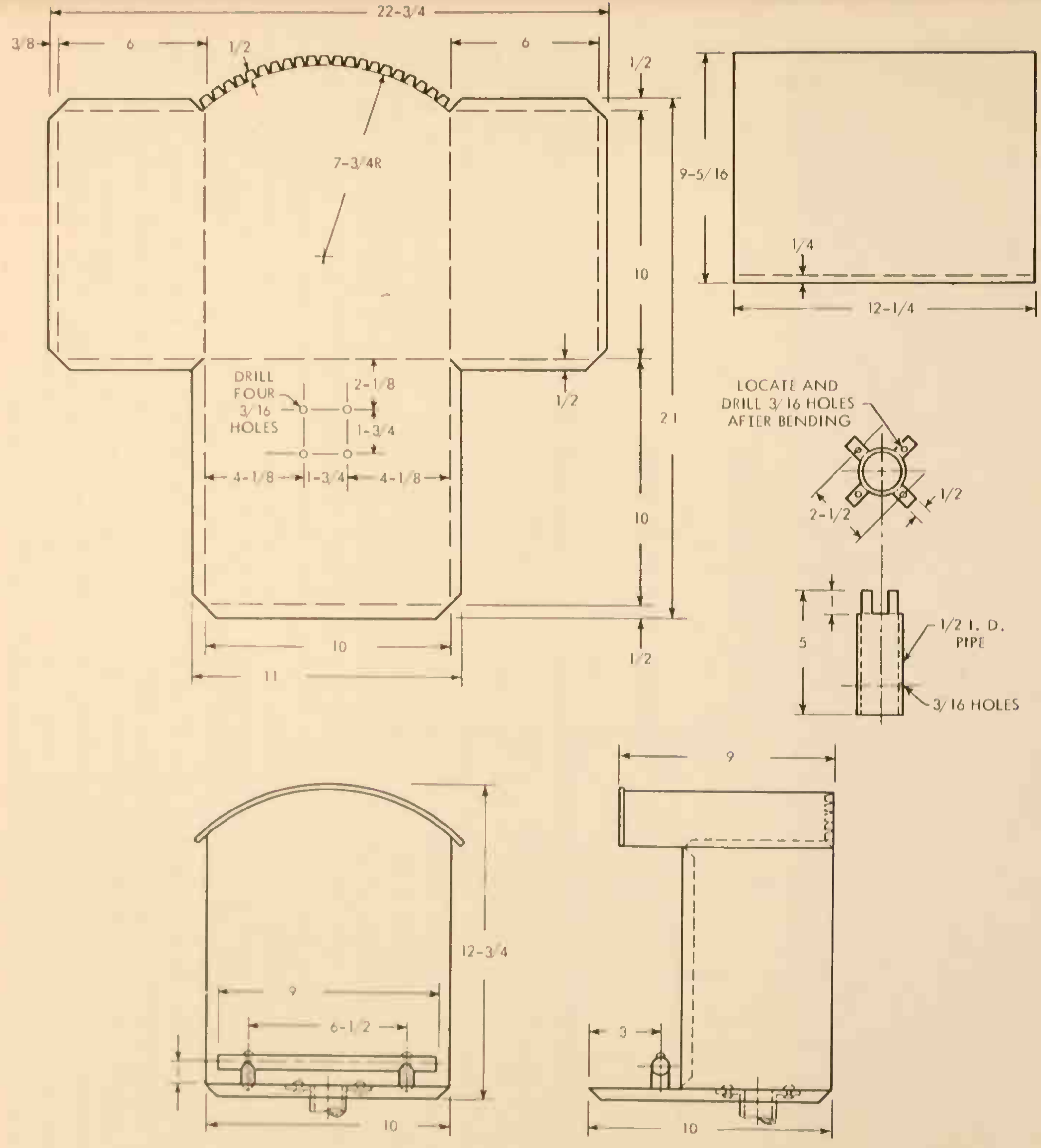


Fig. 10-14. Bird feeder, working drawing.

Fig. 10-15. Fishing tackle box.

FISHING TACKLE BOX

The handy box, Fig. 10-15, can be used to carry your favorite lures, hooks, and sinkers. This unique box which has two lids is constructed of leather grain pattern aluminum. The hinge arrangement is very simple and the box is held together with only four rivets at one end. Cut out all of the parts, and drill the holes for the rivets except the two holes in each end of the box where the hinge rivets are to be located for the two lids. These holes will be drilled later. Cut and form the catches for the hasps. Make the 90 deg. bend along the two edges of the box. Bend the corners of the box to form a rectangular shape. Put the pieces which form the compartments, Nos. (4) and (5), Fig. 10-16, together. The slots in these pieces can be cut out by clamping the four pieces together and cutting them with a hacksaw. After the compartments have been assembled, place part No. (3) between them and insert these pieces in the box. Insert the rings, No. (7) in the ring straps, No. (8) and rivet them to the ends of the box. Bend the sides of the lids. Place one of the lids in position, and check to be sure it will clear all of the sides of the box when opened and closed. Mark the rivet locations on the box for the lid hinge. Drill the holes and set the rivets. Repeat these operations for the other lid. A piece of metal bent to clear the rim of the box, (clamped in a vise), will make it easier to set and head the rivets. Polish the box with steel wool.

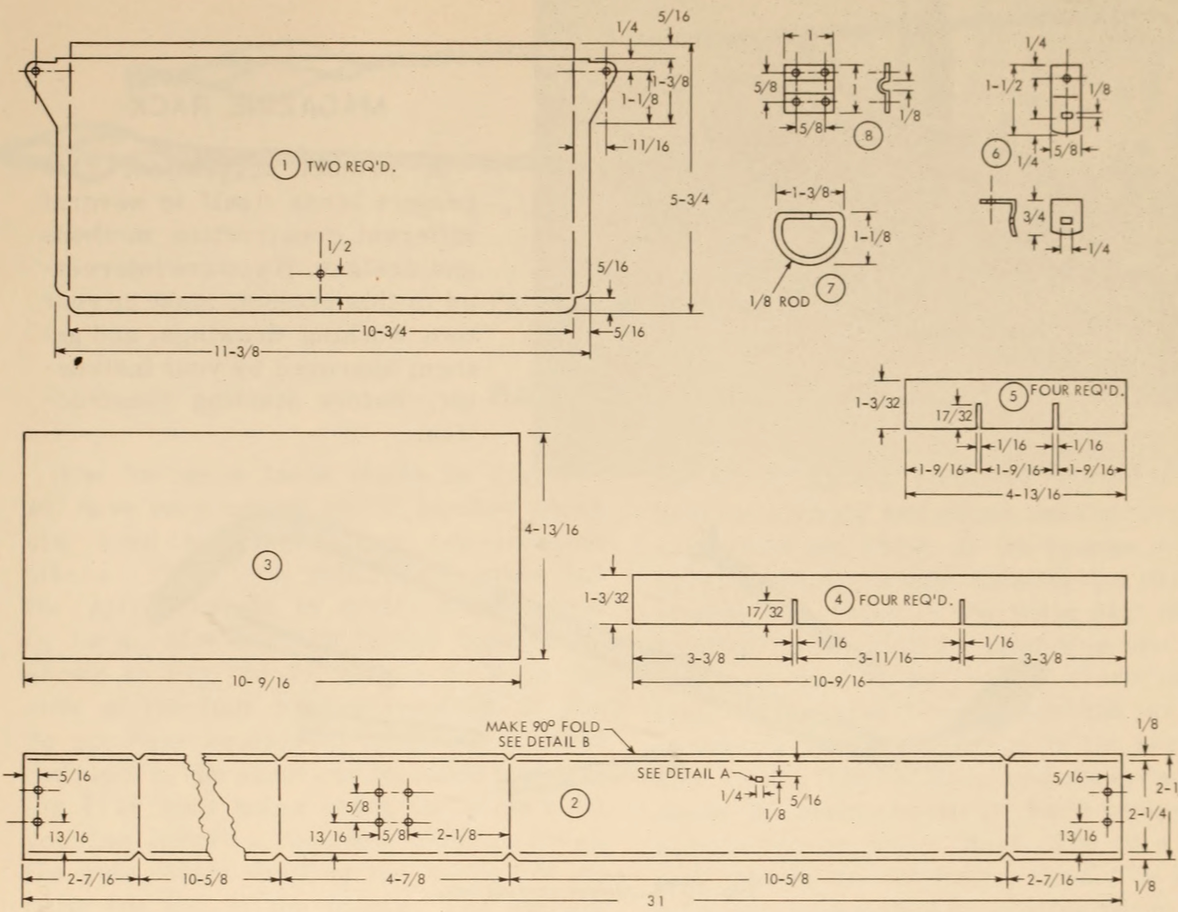
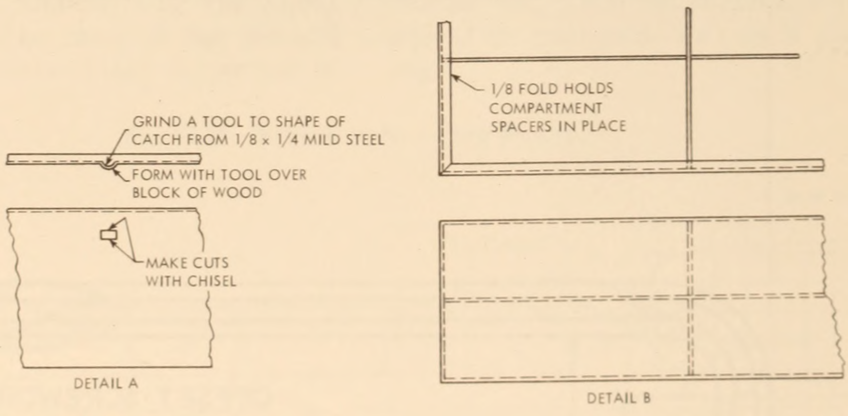


Fig. 10-16. Fishing tackle box, working drawing.



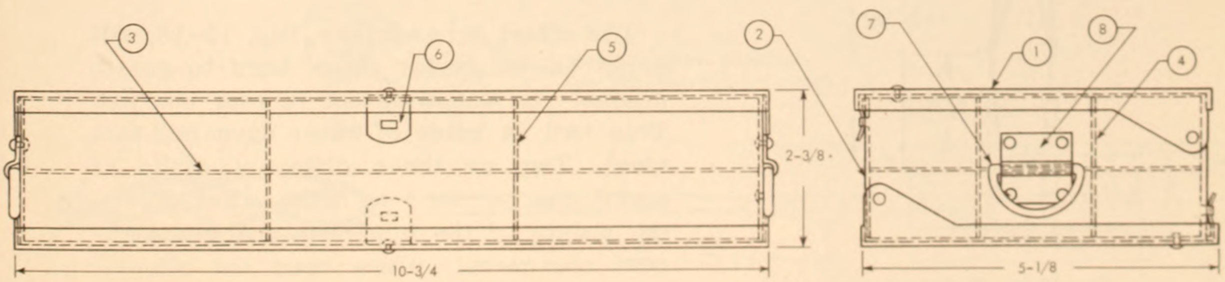
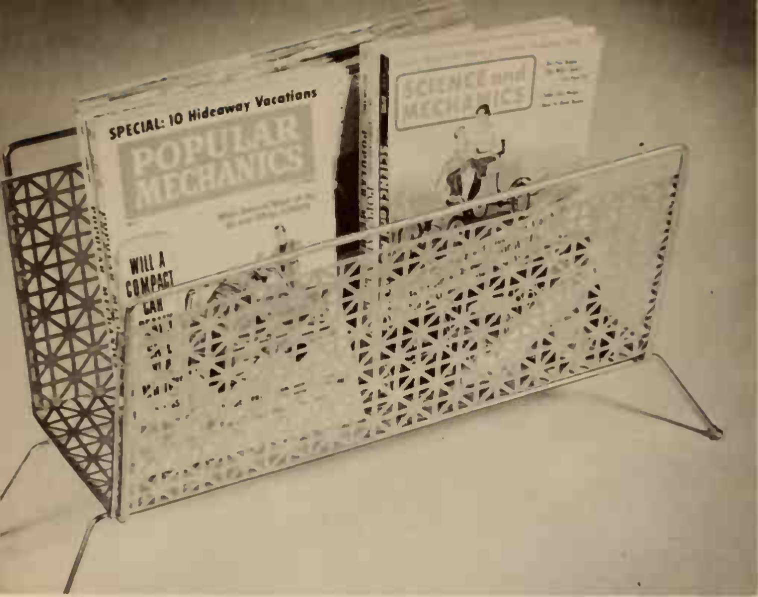


Fig. 10-17. Fishing tackle box, assembly drawing.



MAGAZINE RACK

A project suggestion. This project lends itself to several different construction methods and designs. If you are interested in this project, make up your own working drawings, and get them approved by your instructor, before starting construction.

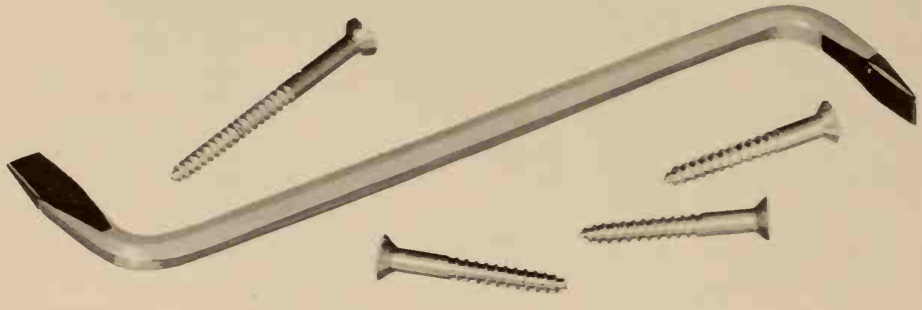


Fig. 10-18. Offset screwdriver.

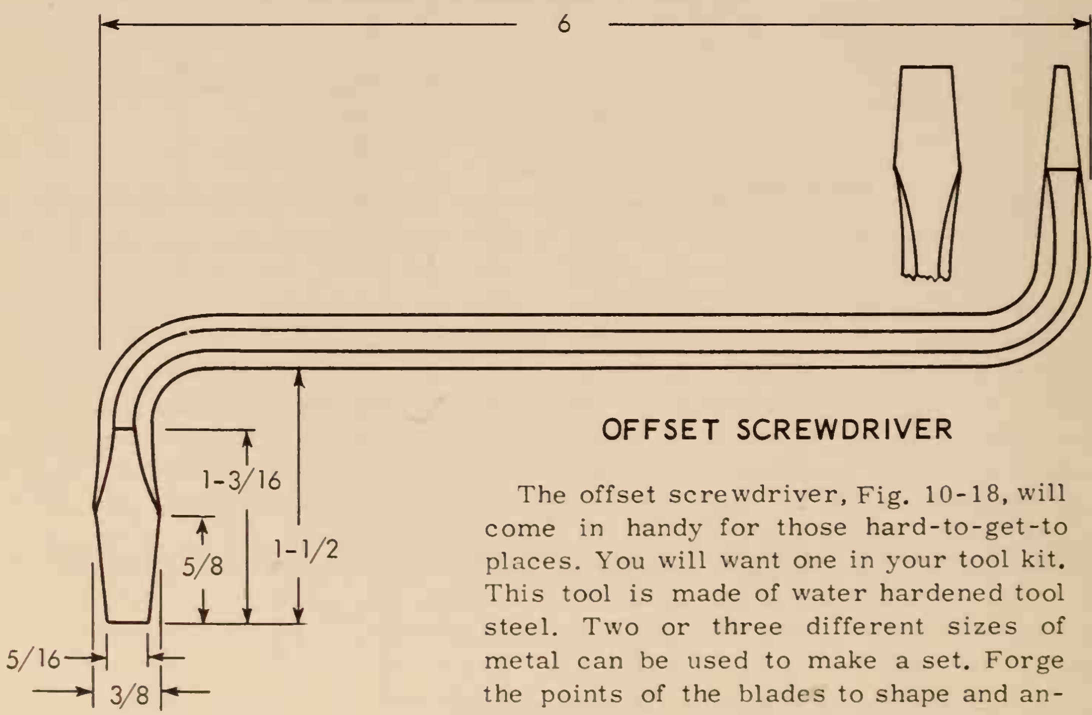


Fig. 10-19. Working drawing.

OFFSET SCREWDRIVER

The offset screwdriver, Fig. 10-18, will come in handy for those hard-to-get-to places. You will want one in your tool kit. This tool is made of water hardened tool steel. Two or three different sizes of metal can be used to make a set. Forge the points of the blades to shape and anneal the metal. Then bend the offsets. Harden and temper the points.

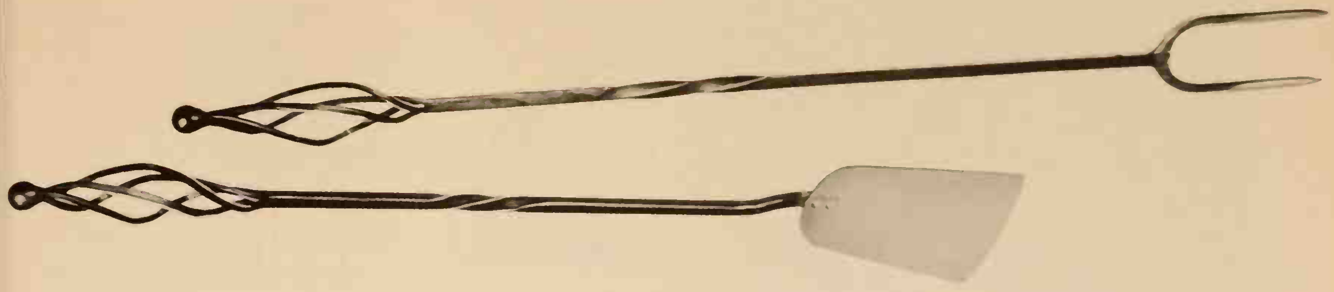


Fig. 10-20. Barbecue tools.

BARBECUE TOOLS

The barbecue tools shown in Fig. 10-20, have very unique spiral handles which are sure to make them conversation pieces. They look difficult to make but the spiral handle is really very simple to form. Slot one end of the handles as shown in Fig. 10-21. Braze or weld the ends of the four prongs together. If you do not have equipment to braze or weld the pieces, the slots can be made by drilling 1/16 inch holes along the slots until you can insert a hacksaw blade to finish the cuts. Start drilling the holes 1/4 in. from the end of the handle. The spirals are formed by clamping the end of the metal in a vise and twisting the metal with a wrench. The jaws of the wrench should grip the metal close to the end of the slots. As the metal is twisted it will become shorter and cause the four prongs to spread and twist. If the prongs do not spread evenly, shape them with a pair of pliers. The twist in the solid part of the handles is formed by clamping one end of the section to be twisted close to the edge of the vise jaws. Place the jaws of a wrench at the other end of the section and twist. The spatula and fork can be made of stainless steel, hard tempered aluminum, or sheet steel. The fork and and spatula should be polished. The handles can be finished by coating them with oil and heating the metal until the oil is burned off. Then the surface of the metal should be polished, using a soft clean rag.

Fig. 10-21. Barbecue tools, working drawing.

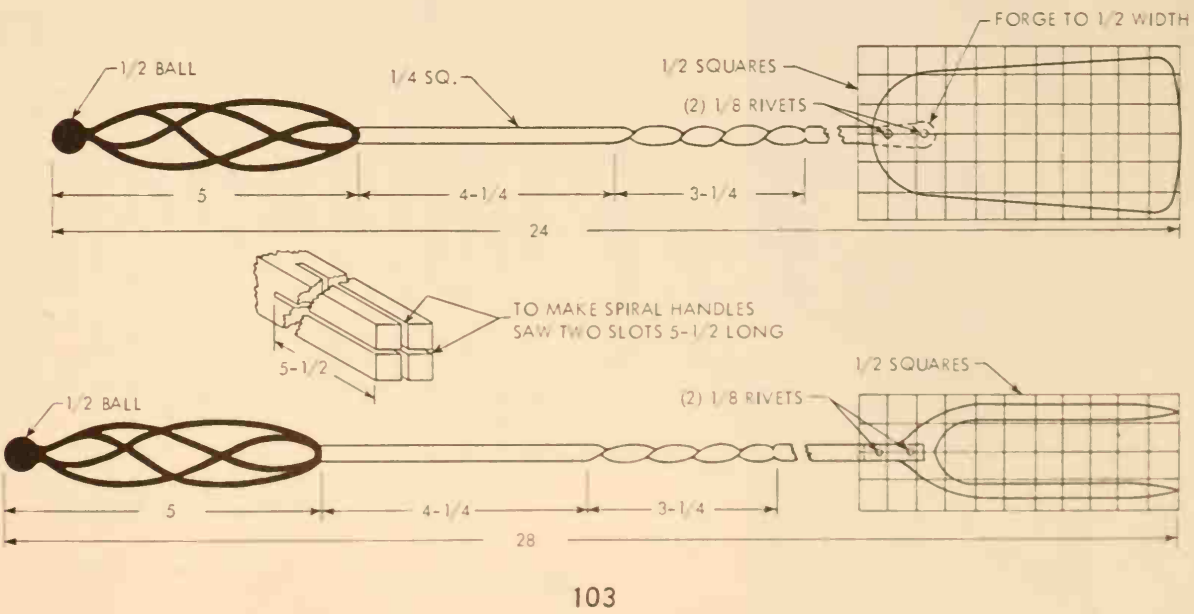


Fig. 10-22. Cigarette set.

CIGARETTE SET

The attractive set shown in Fig. 10-22, will enhance any coffee or end table. They are cast out of aluminum, and given a pleasing buffed finish. When you make the patterns, include a shank 3/4 in. in diameter, and about 1 1/4 in. long on the bottom of them. The shank on the casting makes it easier to chuck the pieces for inside turning. The knob on the lid of the cigarette box can be chucked to turn the lip. Then chuck the lid by the lip to turn the knob and top of lid. After turning the inside and outside of the castings, cut the shanks off and true up the bases. These pieces may be given a highly buffed or satin finish. Glue piece of felt on the bottoms of these projects.

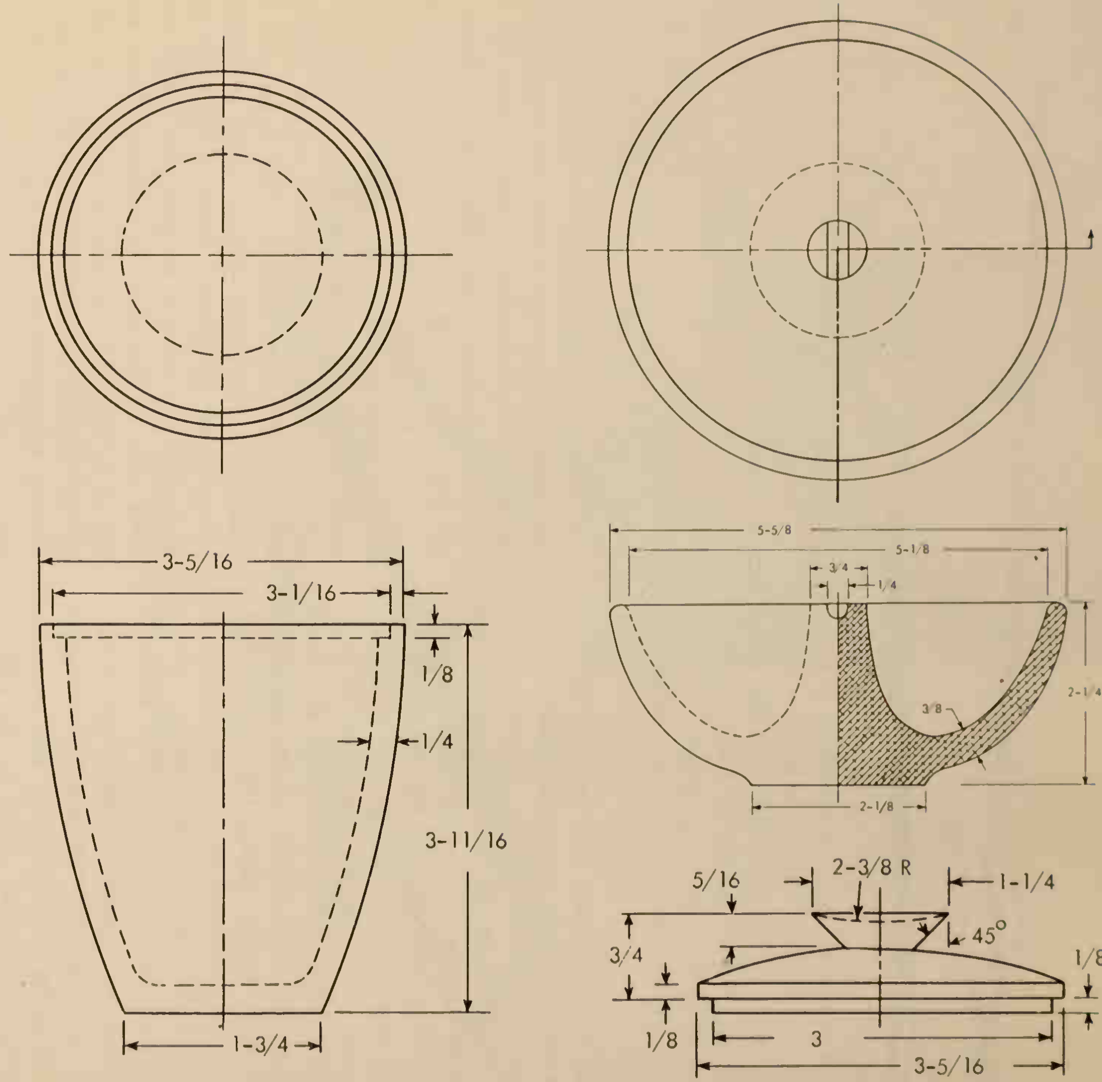


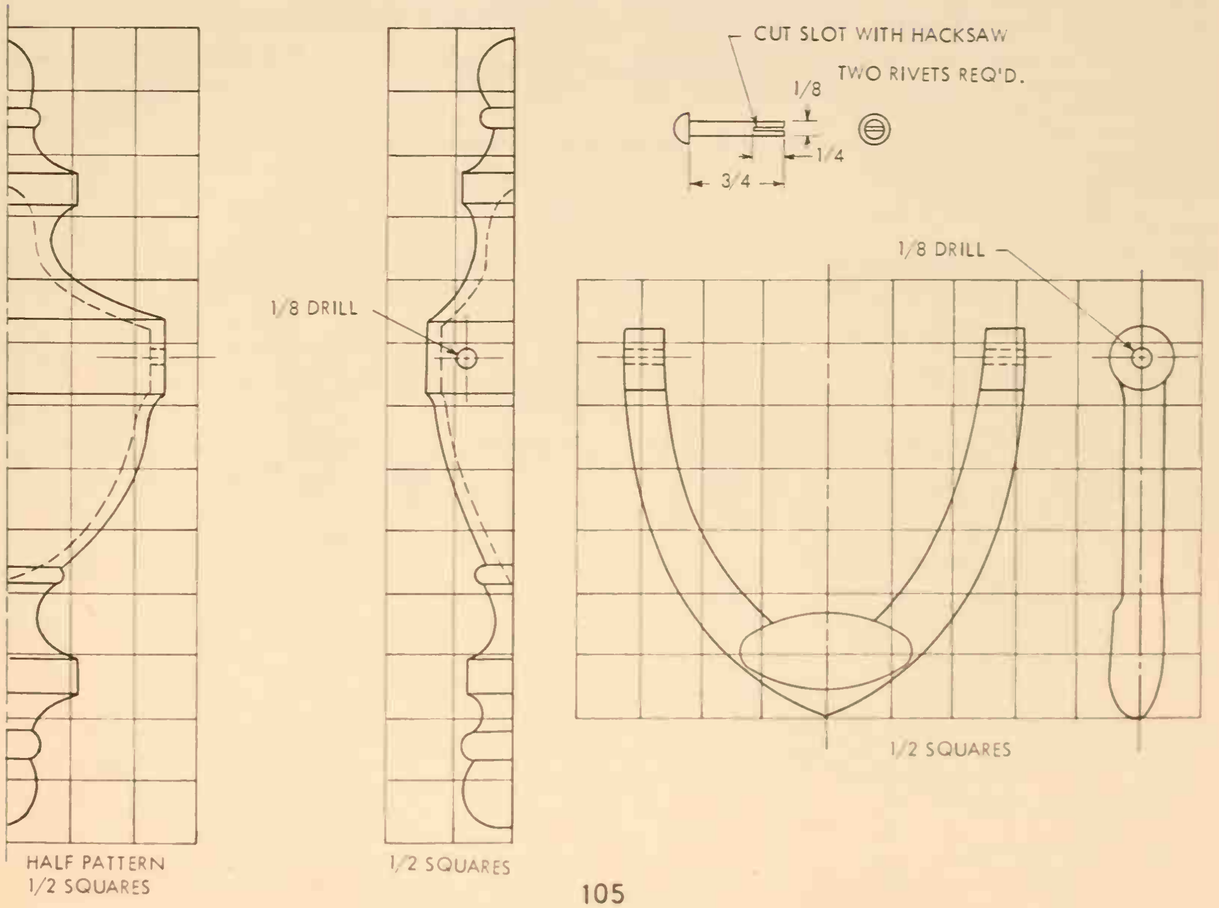
Fig. 10-23. Cigarette set, working drawing.

DOOR KNOCKER

The classic grace of Colonial design in the door knocker, Fig. 10-24, will add distinction to any door. It may be cast in aluminum or brass. The pattern can either be carved out of wood or modeled in clay which is used to make a plaster of Paris mold. The plaster of Paris mold is then used to cast a metal pattern that can be used for green sand foundry work. A hole is drilled in the back side of the knocker plate at the top and at the bottom for a 10-24 machine screw to attach the knocker to a door. The striker is fastened to the plate with two rivets, Fig. 10-25. If aluminum is used, a satin finish is very attractive. Brass is generally given a buffed finish, and should be lacquered to prevent tarnishing.

Fig. 10-24. Door knocker.

Fig. 10-25. Door knocker, working drawing.



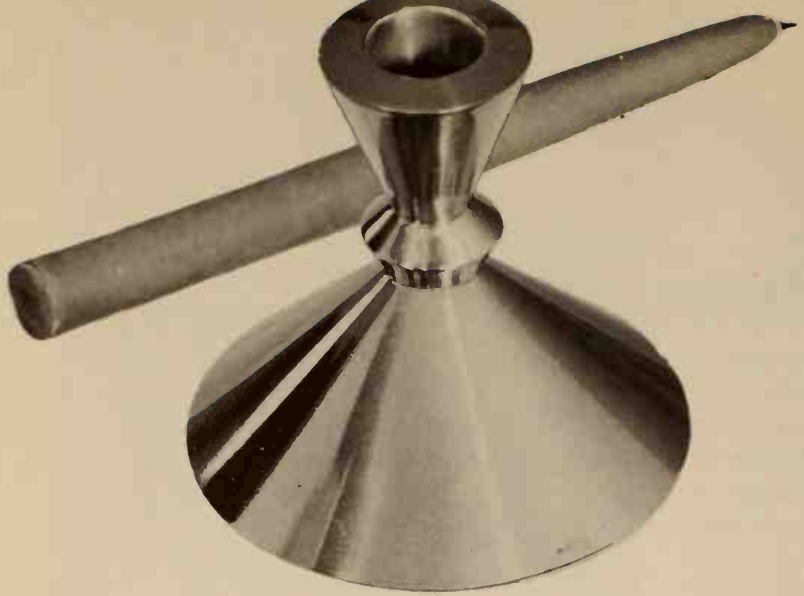
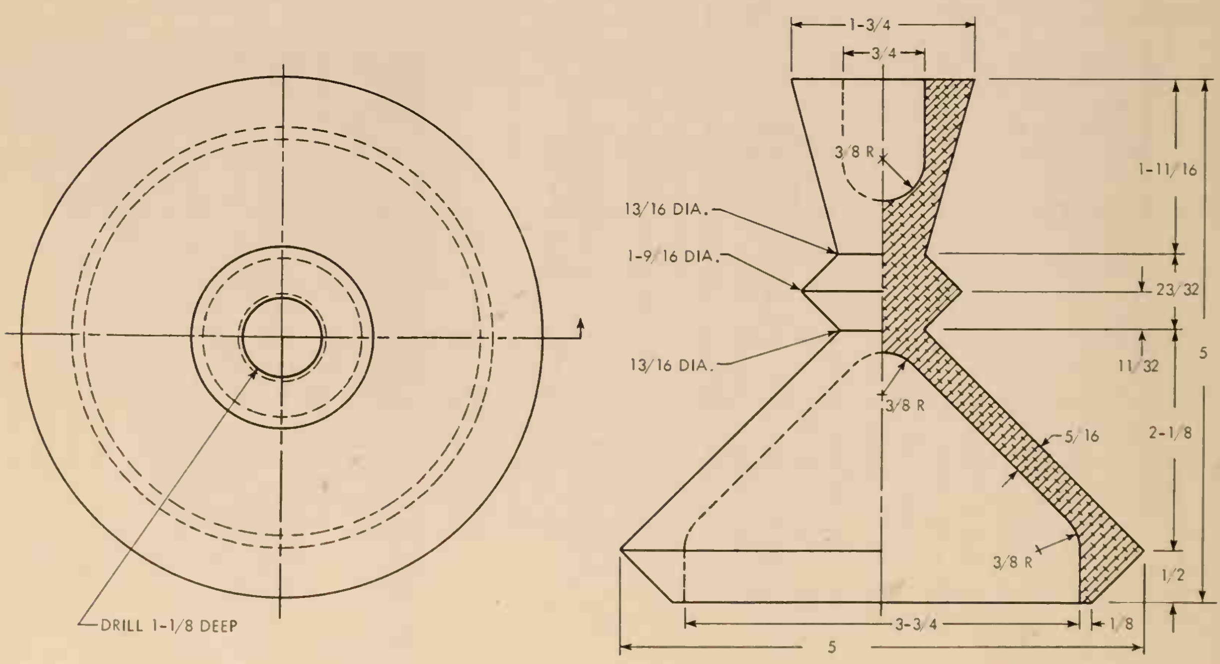


Fig. 10-26. Candle holder.

CANDLE HOLDER

The light reflections given off of the flat tappered surfaces of the candle holder, Fig. 10-26 , makes it a most beautiful piece that will blend with modern or traditional trends. This project requires two patterns and a core mold. A one-piece pattern is made for the base, and a split-pattern is used for the stem and holder. A shank is cast on each part to provide a means for chucking. The hole for the candle is formed with a core. The project is attractive cast in either aluminum or brass. Turn the holder to shape in the lathe and drill and tap the stem for a 10-24 x 1 in. machine screw. Turn the base to shape, and drill a clearance hole through the center for a 10-24 machine screw which is used to join the holder and stem to the base. A highly buffed polish brings out the beauty in this project.

Fig. 10-27. Candle holder, working drawing.



MARKING GAUGE

The marking gauge shown in Fig. 10-28, is a handy tool you can make for your home workshop. This project can be made with hand tools, however, a lathe provides an easy way to make the set screws and fine adjustment nut. The groove in the graduated beam can be cut by mounting the stock between centers in the lathe and securing the headstock spindle so it can not turn. Grind a 1/16 in. radius on the end of the tool bit, and mount in the tool holder in a position which will allow it to cut the groove as the saddle of lathe is fed longitudinally along the lathe bed. The cutting action should take place as the tool bit is fed toward the headstock by hand. Feed the tool bit in about .002 in. for each cut until a depth of .031 in. is reached. The hole for the pointer is drilled for a press fit. Another method which might be used, would be to cut a slot about 1/4 in. deep at the pointer end, and drill the hole small enough so when the pointer is inserted there will be enough spring back to hold the pointer firmly. A small chisel can be used to cut the graduations. The numbers are cut in the beam with steel figure stamps. The figure stamps have to be rolled, as they are hammered in order to obtain an even impression at the top, and bottom of the figures stamped on the beam. The marking gauge head and the fine adjustment head should be clamped together for drilling so the holes of the two pieces will be in line. Mild steel can be used for all of the parts except the adjustment screw. Drill rod is used to make the screw. Caseharden all of the mild steel parts. After the parts have been casehardened, clean and polish them.

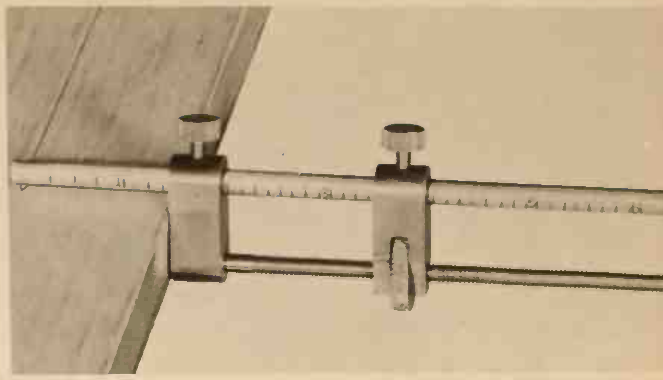
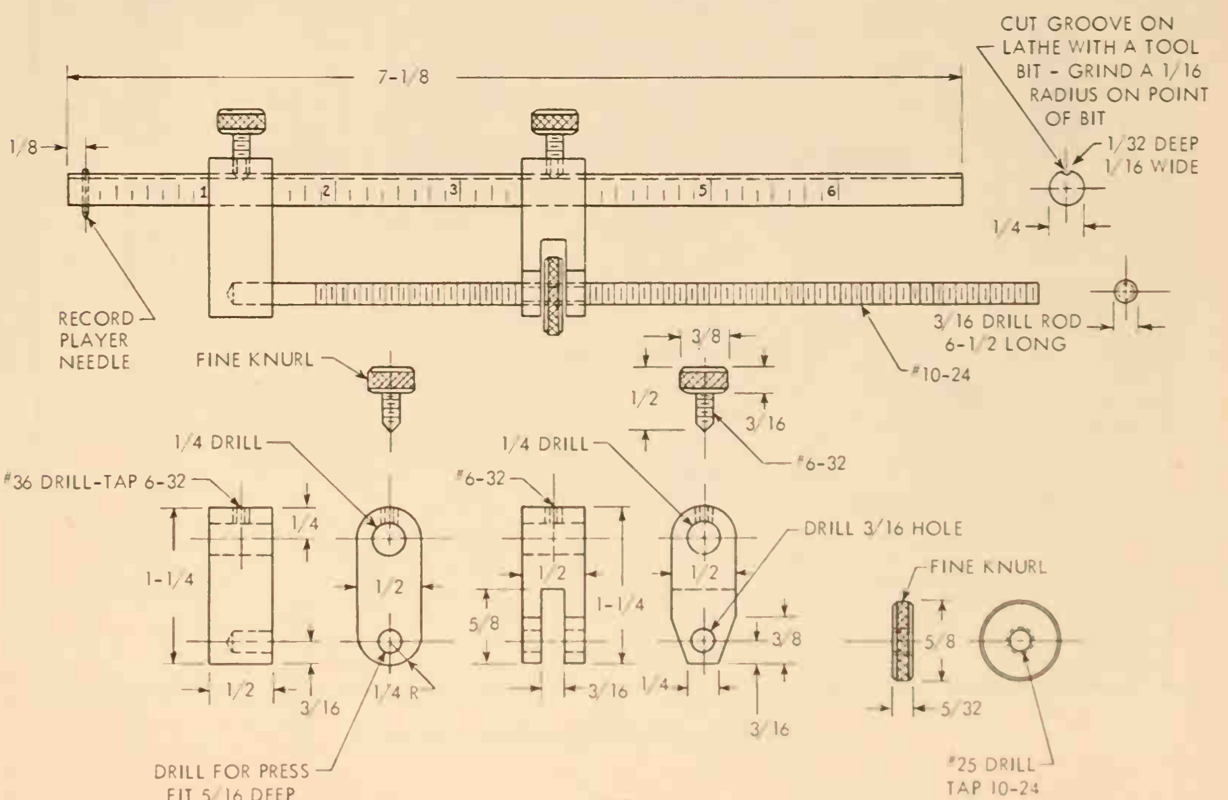


Fig. 10-28. Marking gauge.

Fig. 10-29. Marking gauge, working drawing.



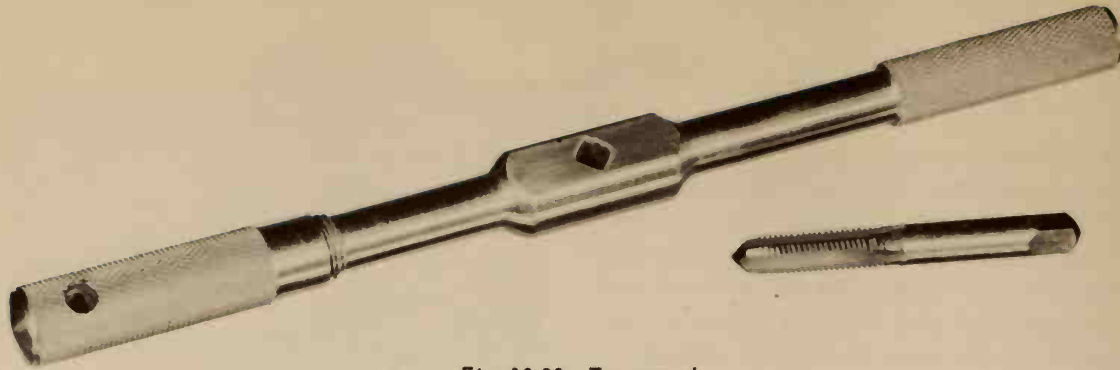


Fig. 10-30. Tap wrench.

TAP WRENCH

The tap wrench, Fig. 10-30, is another tool that will come in handy and one that should be added to your tool kit. Follow the drawing, Fig. 10-31, to construct this project. All of the parts are made in the lathe, even the winding of the spring. The 9/16 in. hole in the end of the adjusting handle should be drilled and tapped in the lathe. The threads on the right end of the body can be threaded in the lathe, or with a threading die. If a threading die is used, great care must be taken to start the threads straight. The square hole in the body is made by drilling first with a 7/32 in. drill, then filing the hole square with a square file. The wrench parts which are made from cold rolled steel should be casehardened.

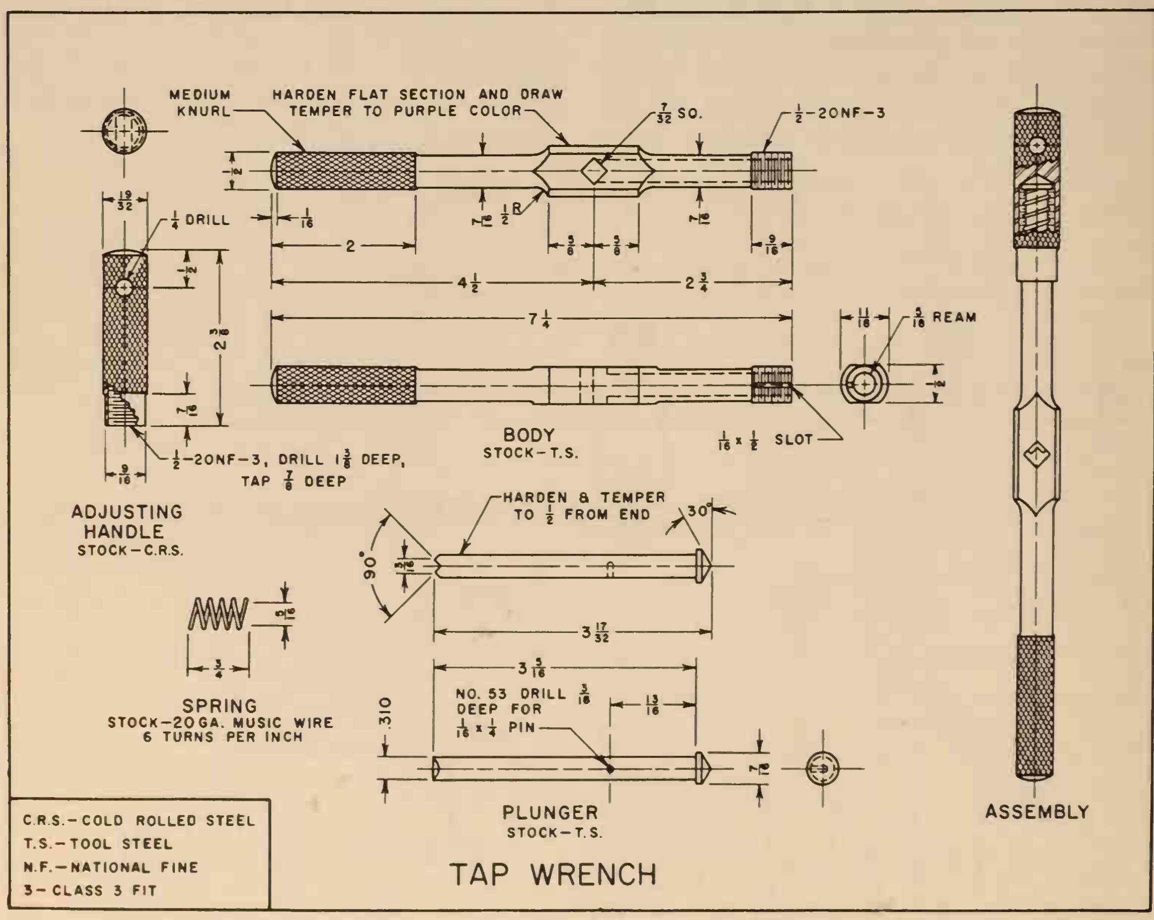


Fig. 10-31. Tap wrench, working drawing.

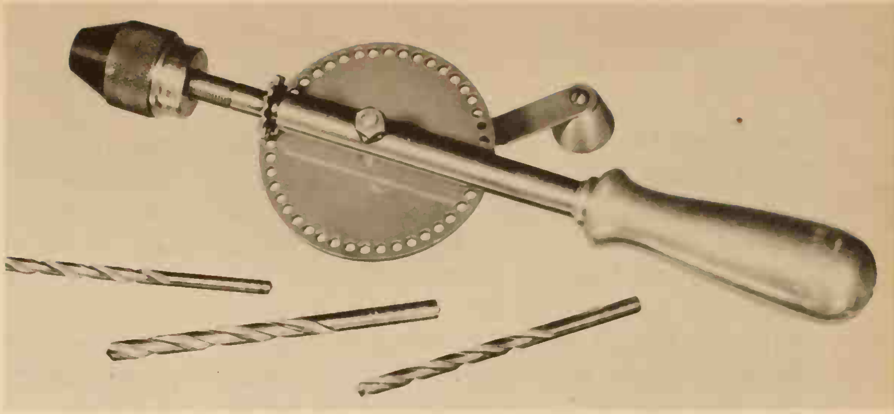
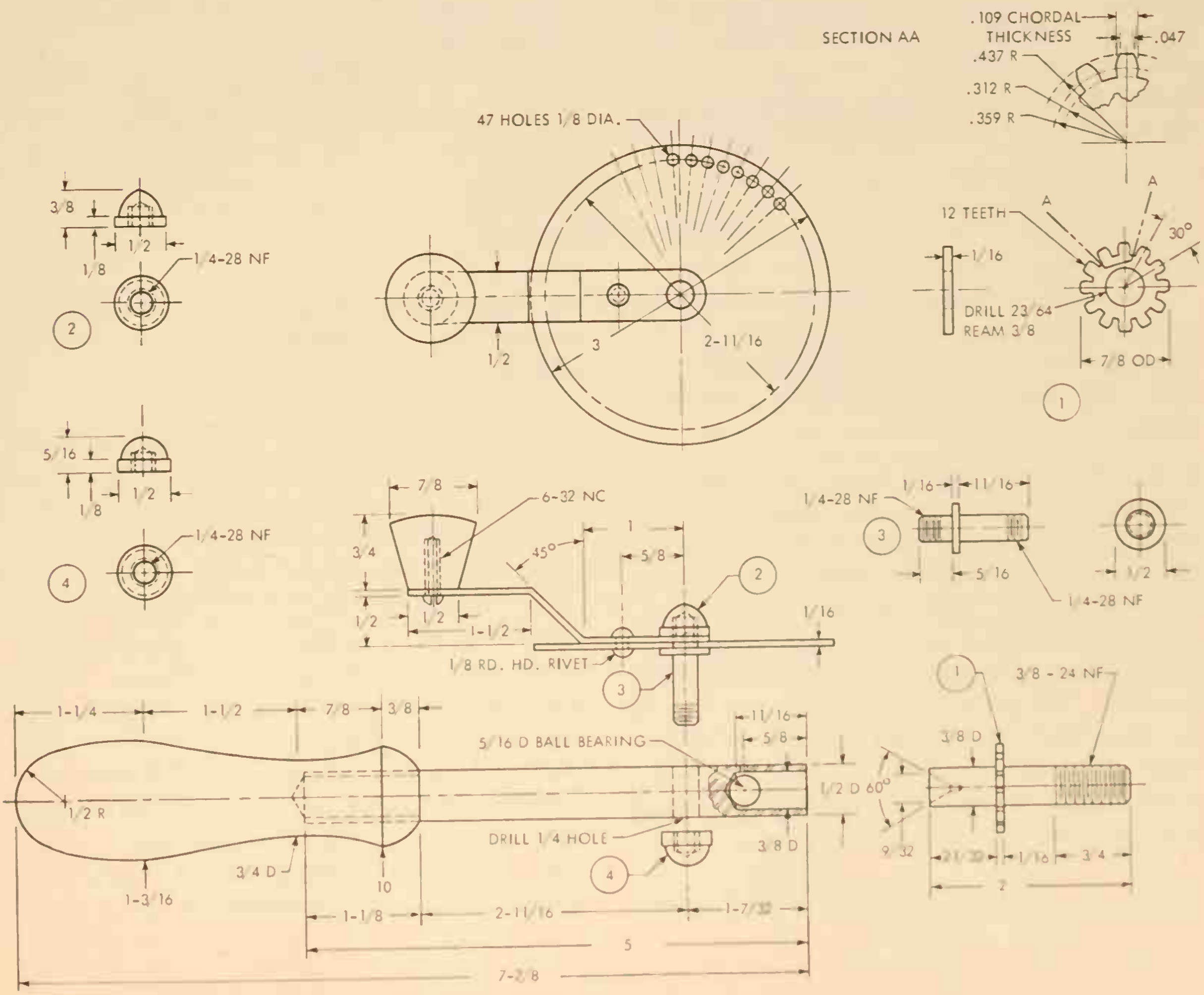


Fig. 10-32. Hand drill.

HAND DRILL

The hand drill, Fig. 10-32, is a very interesting and challenging project. You should not attempt to make this project until you have completed several metal projects successfully. The only machines required are the drill press and lathe. All of the parts can be made of mild steel except the handle which should be made of aluminum or wood to give the tool better balance. A 3-jaw, 1/4 in. chuck can be purchased from a hardware store. The chuck shaft gear and the drive wheel are the two most difficult pieces to make. The drive wheel must be accurately laid out and drilled in order to work properly. The teeth on the gear are made by drill-

Fig. 10-33. Hand drill, working drawing.



ing 3/64 in. holes between them, close to the root circle, and then cutting out the surplus metal left between the teeth with a hacksaw. Finish the gear by filing to the layout lines. A jig can be developed that can be used to drill evenly spaced holes in the drive wheel. Work with your instructor and see if you can design a jig for this operation. After all of the parts have been made, attach the drive wheel to the body of the drill. Insert the ball bearing and chuck shaft in the end of the body. Hold the chuck shaft tightly against the ball bearing, and adjust the gear on the shaft until the teeth match perfectly with the holes in the drive wheel. The chuck shaft gear can be attached by brazing. If you do not have this equipment, you can use a 1/16 in. key between the shaft and the gear, and hard solder the pieces together. After the gear has been joined to the shaft, assemble the drill, and test it to see if the gear teeth mesh with the holes in the drive wheel as you turn the crank. File off the high spots on the teeth of the gear that do not mesh. The project can be finished by painting some of the parts or by polishing all of the surfaces.

For Your Further Study

Felker, C. A.: Machine Shop Technology, The Bruce Publ. Co., Milwaukee, Wisc.

Giachino, J.W. and Feirer, J. L.: Basic Metal Practice, Chas. A. Bennett Co., Inc., Peoria, Ill.

Ludwig, O.A.: Metalwork Technology and Practice, McKnight and McKnight Publ. Co., Bloomington, Ill.

Smith, R. E.: Forging and Welding, McKnight and McKnight Pub. Co., Bloomington, Ill.

Smith, R. E.: Patternmaking and Founding, McKnight and McKnight Pub. Co., Bloomington, Ill.

Stieri, E.: Sheet Metal Principles and Procedures, Prentice-Hall, Inc., Englewood Cliffs, N. J.

Yerkow, C.: Fundamentals of Soft Soldering, Chas. A. Bennett Co., Inc., Peoria, Ill.

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